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THE MECHANICAL PROPERTY DATA BASE FROM AN
AIR FORCE/INDUSTRY COOPERATIVE TEST PROGRAM ON ADVANCED
ALUMINUM ALLOYS (7064 AND CW67)

MARY ANN PHILLIPS and STEVEN R. THOMPSON
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AUGUST 1993

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Interim Report for Period December 1986 - May 1990

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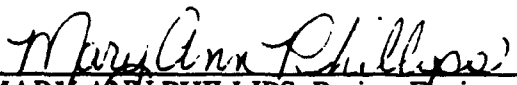
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Do not use this form for information other than that requested. 45. Do not use this form for information other than that requested. 46. Do not use this form for information other than that requested. 47. Do not use this form for information other than that requested. 48. Do not use this form for information other than that requested. 49. Do not use this form for information other than that requested. 50. Do not use this form for information other than that requested. 51. Do not use this form for information other than that requested. 52. Do not use this form for information other than that requested. 53. Do not use this form for information other than that requested. 54. Do not use this form for information other than that requested. 55. Do not use this form for information other than that requested. 56. Do not use this form for information other than that requested. 57. Do not use this form for information other than that requested. 58. Do not use this form for information other than that requested. 59. Do not use this form for information other than that requested. 60. Do not use this form for information other than that requested. 61. Do not use this form for information other than that requested. 62. Do not use this form for information other than that requested. 63. Do not use this form for information other than that requested. 64. Do not use this form for information other than that requested. 65. Do not use this form for information other than that requested. 66. Do not use this form for information other than that requested. 67. Do not use this form for information other than that requested. 68. Do not use this form for information other than that requested. 69. Do not use this form for information other than that requested. 70. Do not use this form for information other than that requested. 71. Do not use this form for information other than that requested. 72. Do not use this form for information other than that requested. 73. Do not use this form for information other than that requested. 74. Do not use this form for information other than that requested. 75. Do not use this form for information other than that requested. 76. Do not use this form for information other than that requested. 77. Do not use this form for information other than that requested. 78. Do not use this form for information other than that requested. 79. Do not use this form for information other than that requested. 80. Do not use this form for information other than that requested. 81. Do not use this form for information other than that requested. 82. Do not use this form for information other than that requested. 83. Do not use this form for information other than that requested. 84. Do not use this form for information other than that requested. 85. Do not use this form for information other than that requested. 86. Do not use this form for information other than that requested. 87. Do not use this form for information other than that requested. 88. Do not use this form for information other than that requested. 89. Do not use this form for information other than that requested. 90. Do not use this form for information other than that requested. 91. Do not use this form for information other than that requested. 92. Do not use this form for information other than that requested. 93. Do not use this form for information other than that requested. 94. Do not use this form for information other than that requested. 95. Do not use this form for information other than that requested. 96. Do not use this form for information other than that requested. 97. Do not use this form for information other than that requested. 98. Do not use this form for information other than that requested. 99. Do not use this form for information other than that requested. 100. 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| 1. AGENCY USE ONLY Leave | 2. REPORT DATE August 1993 | 3. REPORT TYPE AND DATES COVERED INTERIM 12/01/86--05/01/90 | | |
| 4. TITLE AND SUBTITLE The Mechanical Property Data Base from an Air Force/ Industry Cooperative Test Program on Advanced Aluminum Alloys (7064 and CW67) | | 5. FUNDING NUMBERS PE 62102F PR 2418 TA 07 WU 03 | | |
| 6. AUTHOR(S) Mary Ann Phillips Steven R. Thompson | | 8. PERFORMING ORGANIZATION REPORT NUMBER WL-TR-93-4090 | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Materials Directorate Wright Laboratory Air Force Materiel Command Wright Patterson AFB OH 45433-7718 | | | | |
| 9. SPONSORING MONITORING AGENCY NAME(S) AND ADDRESS(ES) Materials Directorate Wright Laboratory Air Force Materiel Command Wright Patterson AFB OH 45433-7718 | | 10. SPONSORING / MONITORING AGENCY REPORT NUMBER WL-TR-93-4090 | | |
| 11. SUPPLEMENTARY NOTES | | | | |
| 12a. DISTRIBUTION AVAILABILITY STATEMENT Approved for Public Release; Distribution is unlimited. | | | 12b. DISTRIBUTION CODE | |
| 13. ABSTRACT (Maximum 200 words) A mechanical property data base on Kaiser produced second generation P/M alloys 7064 forging and extrusion and Alcoa produced P/M alloys CW67 sheet, plate, forging and extrusion was generated. Mechanical property data consisted of tension, compression, shear, bearing and fracture toughness values. Fatigue, fatigue crack growth and spectrum fatigue crack growth data were generated. | | | | |
| 14. SUBJECT TERMS CW67 tension bearing spectrum 7064 compression fatigue R-curve P/M shear fracture toughness | | | 15. NUMBER OF PAGES 130 | |
| 17. SECURITY CLASSIFICATION OF REPORT Unclassified | | | 16. PRICE CODE | |
| 18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified | | 19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified | | 20. LIMITATION OF ABSTRACT UL |

TABLE OF CONTENTS

| <u>SECTION</u> | | | <u>PAGE</u> |
|-------------------|------------------------|-----------|-------------|
| 1. | INTRODUCTION | | 1 |
| 2. | MATERIALS AND TESTS | | 3 |
| 3. | PRESENTATION | | 4 |
| 4. | RESULTS AND DISCUSSION | | 5 |
| 5. | CONCLUSIONS | | 6 |
| <u>APPENDICES</u> | | | |
| APPENDIX N | 7064 | EXTRUSION | 7 |
| APPENDIX O | 7064 | FORGING | 24 |
| APPENDIX P | CW67 | SHEET | 48 |
| APPENDIX Q | CW67 | PLATE | 65 |
| APPENDIX R | CW67 | EXTRUSION | 70 |
| APPENDIX S | CW67 | FORGING | 100 |

LIST OF FIGURES

| <u>FIGURE</u> | <u>PAGE</u> |
|---|--------------------|
| N1 Fatigue Results for 7064-T74511 Extrusion (Longitudinal Orientation) LTV | 17 |
| N2 Fatigue Crack Growth Rate Data for Two 7064-T74511 Extrusion Specimens (L-T). Air Force. | 18 |
| N3 Fatigue Crack Growth Rate Data for Two 7064-T74511 Extrusion Specimens (T-L). Air Force. | 19 |
| N4 Mini-TWIST Spectrum Fatigue Crack Length vs Flights Data for 7064-T74511 Extrusion. Air Force. | 20 |
| N5 Mini-TWIST Spectrum Fatigue Crack Growth Rate Data for 7064-T74511 Extrusion. Air Force. | 21 |
| N6 FALSTAFF Spectrum Fatigue Crack Length vs Flights Data for 7064-T74511 Extrusion. Air Force. | 22 |
| N7 FALSTAFF Spectrum Fatigue Crack Growth Rate Data for 7064-T74511 Extrusion. Air Force. | 23 |
| O1 Fatigue Data for 7064-T74 Forging (Longitudinal Orientation, R=0.1, Kt=1 and Kt=3). LTV. | 40 |
| O2 Fatigue Data for 7064-T74 Forging (Longitudinal Orientation, R=-1.0, and Kt=1). McDonnell Aircraft Company. | 42 |
| O3 Fatigue Crack Growth Rate Data for 7064-T74 Forging (T-L Orientation, WOL Type Specimen). McDonnell Aircraft Company. | 43 |
| O4 Mini-TWIST Spectrum Fatigue Crack Length vs Flights Data for 7064-T74 Forging. Air Force. | 44 |
| O5 Mini-TWIST Spectrum Fatigue Crack Growth Rate Data for 7064-T74 Forging. Air Force. | 45 |
| O6 FALSTAFF Spectrum Fatigue Crack Length vs Flights Data for 7064-T74 Forging. Air Force. | 46 |
| O7 FALSTAFF Spectrum Fatigue Crack Growth Rate Data for 7064-T74 Forging. Air Force. | 47 |
| P1 R-Curve Data for CW67 Sheet (L-T Orientation). | 58 |
| P2 R-Curve Effective Crack Length Adjusted for Plastic Zone (L-T Orientation). | 58 |

| FIGURE | | PAGE |
|---------------|---|-------------|
| P3 | Fatigue Crack Growth Rate Data for CW67 Sheet (L-T Orientation, R=0.1, Lab Air and RT) McDonnell Aircraft Company. | 61 |
| P4 | Fatigue Crack Growth Rate Data for CW67 Sheet (L-T Orientation,, R=0.33, Lab Air and RT,. McDonnell Aircraft Company. | 62 |
| P5 | Fatigue Crack Growth Rate Data for CW67 Sheet (T-L Orientation, R=0.1, Lab Air and RT). McDonnell Aircraft Company. | 63 |
| P6 | Fatigue Crack Growth Rate Data for CW67 Sheet (T-L Orientation, R=0.33, Lab Air and RT). McDonnell Aircraft Company. | 64 |
| Q1 | R-Curve Data for CW67 Plate (L-T Orientation). Martin Marietta. | 67 |
| Q2 | R-Curve Effective Crack Length Adjusted for Plastic Zone Data for CW67 Plate (L-T Orientation). Martin Marietta. | 67 |
| R1 | Fatigue Crack Growth Rate Data for CW67 Extrusion (L-T Orientation and R=0.1). McDonnell Aircraft Company. | 79 |
| R2 | Fatigue Crack Growth Rate Data for CW67 Extrusion (L-T Orientation and R=0.33). McDonnell Aircraft Company. | 80 |
| R3 | Fatigue Crack Growth Rate Data for CW67 Extrusion (T-L Orientation and R=0.1). McDonnell Aircraft Company. | 81 |
| R4 | Fatigue Crack Growth Rate Data for CW67 Extrusion (T-L Orientation and R=0.33). McDonnell Aircraft Company. | 82 |
| R5 | Fatigue Crack Growth Rate Data for CW67 Extrusion (L-T Orientation). Air Force. | 83 |
| R6 | Fatigue Crack Growth Rate Data for CW67 Extrusion (T-L Orientation). Air Force. | 84 |
| R7 | Fatigue Crack Growth Rate Data for CW67 Extrusion (L-T Orientation and High Humidity). Air Force. | 85 |
| R8 | Fatigue Crack Growth Rate Data for CW67 Extrusion (L-T Orientation and Specimen GLT-1). LTV. | 86 |
| R9 | Fatigue Crack Growth Rate Data for CW67 Extrusion (L-T Orientation and Specimen GLT-2). LTV. | 87 |
| R10 | Fatigue Crack Growth Rate Data for CW67 Extrusion (L-T Orientation and Specimen GLT-3). LTV. | 88 |
| R11 | Fatigue Crack Growth Rate Data for CW67 Extrusion (T-L Orientation and Specimen GTL-1). LTV. | 89 |
| R12 | Fatigue Crack Growth Rate Data for CW67 Extrusion (T-L Orientation and Specimen GTL-2). LTV. | 90 |

| FIGURE | | PAGE |
|---------------|--|-------------|
| R13 | Fatigue Crack Growth Rate Data for CW67 Extrusion (T-L Orientation and Specimen GTL-3). LTV. | 91 |
| R14 | Mini-TWIST Spectrum Fatigue Crack Length vs Flights Data for CW67 Extrusion (CSP-2). Air Force. | 92 |
| R15 | Mini-TWIST Spectrum Fatigue Crack Growth Rate Data for CW67 Extrusion (CSP-2) Air Force. | 93 |
| R16 | Mini-TWIST Spectrum Fatigue Crack Length vs Flights Data for CW67 Extrusion (CSP-4). Air Force. | 94 |
| R17 | Mini-TWIST Spectrum Fatigue Crack Growth Rate Data for CW67 Extrusion (CSP-4). Air Force. | 95 |
| R18 | FALSTAFF Spectrum Fatigue Crack Length vs Flights (CSP-1). Air Force. | 96 |
| R19 | FALSTAFF Spectrum Fatigue Crack Growth Rate Data for CW67 Extrusion (CSP-1). Air Force. | 97 |
| R20 | FALSTAFF Spectrum Fatigue Crack Length vs Flights (CSP-3). Air Force. | 98 |
| R21 | FALSTAFF Spectrum Fatigue Crack Growth Rate Data for CW67 Extrusion (CSP-3). Air Force. | 99 |
| S1 | Fatigue Crack Growth Rate Data for CW67 Forging (L-T Orientation). Air Force. | 110 |
| S2 | Fatigue Crack Growth Rate Data for CW67 Forging (T-L Orientation). Air Force. | 111 |
| S3 | Fatigue Crack Growth Rate Data for CW67 Forging (S-T Orientation). Air Force. | 112 |
| S4 | Comparison of CW67 Forging and 7050 Plate Mini-TWIST Spectrum Fatigue Crack Growth Rate Data. Air Force. | 113 |
| S5 | Comparison of CW67 Forging and 7050 Plate FALSTAFF Spectrum Fatigue Crack Growth Rate Data. Air Force. | 114 |

LIST OF TABLES

| <u>TABLE</u> | <u>PAGE</u> |
|---|--------------------|
| N1 Tensile Results at $t/2$ Location for Kaiser 7064-T745 Extrusion, Longitudinal Orientation | 8 |
| N2 Tensile Results at $t/2$ Location for Kaiser 7064-T74511 Extrusion, Long Transverse Orientation | 8 |
| N3 Compression Results at $t/2$ Location for Kaiser 7064-T74511 Extrusion, Longitudinal Orientation | 9 |
| N4 Compression Results at $t/2$ location for Kaiser 7064-T74511 Extrusion, Long Transverse Orientation | 9 |
| N5 Iosipescu Shear Results for Kaiser 7064-T74511 Extrusion, Longitudinal Orientation | 10 |
| N6 Iosipescu Shear Results for Kaiser 7064-T74511 Extrusion, Long Transverse Orientation | 10 |
| N7 Bearing Results for Kaiser 7064-T74511 Extrusion, Longitudinal Orientation and $e/D=1.5$ | 11 |
| N8 Bearing Results for Kaiser 7064-T74511 Extrusion, Longitudinal Orientation and $e/D=2.0$ | 12 |
| N9 Bearing Results for Kaiser 7064-T74511 Extrusion, Long Transverse Orientation and $e/D=2.0$ | 12 |
| N10 Fracture Toughness Results for Kaiser 7064-T74511 Extrusion, L-T Orientation | 13 |
| N11 Fracture Toughness Results for Kaiser 7064-T74511 Extrusion, T-L Orientation | 14 |
| N12 Fatigue Results with $K_t=1.0$ and $R=0.1$ for Kaiser 7064-T74511 Extrusion, Longitudinal Orientation | 15 |
| N13 Fatigue Results with $K_t=3.0$ and $R=0.1$ for Kaiser 7064-T74511 Extrusion, Longitudinal Orientation | 16 |
| O1 Tensile Results at $t/2$ Location for Kaiser 7064-T74 Forging, Longitudinal Orientation | 25 |
| O2 Tensile Results at $t/2$ Location for Kaiser 7064-T74 Forging, Long Transverse Orientation | 26 |
| O3 Tensile Results at $t/2$ Location for Kaiser 7064-T74 Forging, Short Transverse Orientation | 27 |

| <u>TABLE</u> | <u>PAGE</u> |
|---|--------------------|
| O4 Compression Results at $t/2$ Location for Kaiser 7064-T74 Forging, Longitudinal Orientation | 28 |
| O5 Compression Results at $t/2$ Location for Kaiser 7064-T74 Forging, Long Transverse Orientation | 29 |
| O6 Slotted Shear Results for Kaiser 7064-T74 Forging, Longitudinal Orientation | 30 |
| O7 Amsler Double Shear Results for Kaiser 7064-T74 Forging, L-T Orientation | 30 |
| O8 Iosipescu Shear Results for Kaiser 7064-T74 Forging, Longitudinal Orientation | 31 |
| O9 Iosipescu Shear Results for Kaiser 7064-T74 Forging, Long Transverse Orientation | 31 |
| O10 Bearing Results for Kaiser 7064-T74 Forging, Longitudinal Orientation and $c/D=1.5$ | 32 |
| O11 Bearing Results for Kaiser 7064-T74 Forging, Long Transverse Orientation and $c/D=1.5$ | 32 |
| O12 Bearing Results for Kaiser 7064-T74 Forging, Longitudinal Orientation and $c/D=2.0$ | 33 |
| O13 Bearing Results for Kaiser 7064-T74 Forging, Long Transverse Orientation and $c/D=2.0$ | 33 |
| O14 Fracture Toughness Results for Kaiser 7064-T74 Forging, L-T Orientation | 34 |
| O15 Fracture Toughness Results for Kaiser 7064-T74 Forging, T-L Orientation | 35 |
| O16 Fracture Toughness Results for Kaiser 7064-T74 Forging, S-T Orientation | 36 |
| O17 Fracture Toughness Results for Kaiser 7064-T74 Forging, S-L Orientation | 37 |
| O18 Fatigue Results for Kaiser 7064-T74 Forging (Longitudinal Orientation, $K_t=1.0$ and $R=0.1$) | 38 |
| O19 Fatigue Results for Kaiser 7064-T74 Forging (Longitudinal Orientation, $K_t=3.0$ and $R=0.1$) | 39 |
| O20 Fatigue Results for Kaiser 7064-t74 Forging (Longitudinal Orientation, $K_t=1.0$ and $R=-1.0$) | 41 |

| <u>TABLE</u> | <u>PAGE</u> |
|---|--------------------|
| P1 Tensile Results for Alcoa CW67 Sheet, Longitudinal Orientation | 49 |
| P2 Tensile Results for Alcoa CW67 Sheet, Long Transverse Orientation | 49 |
| P3 Compression Results for Alcoa CW67 Sheet, Longitudinal Orientation | 50 |
| P4 Compression Results for Alcoa CW67 Sheet, Long Transverse Orientation | 50 |
| P5 Slotted Shear Results for Alcoa CW67 Sheet, Longitudinal Orientation | 51 |
| P6 Bearing Results for Alcoa CW67 Sheet, Longitudinal Orientation and $e/D=1.5$ | 52 |
| P7 Bearing Results for Alcoa CW67 Sheet, Long Transverse Orientation and $e/D=1.5$ | 52 |
| P8 Bearing Results for Alcoa CW67 Sheet, Longitudinal Orientation and $e/D=2.0$ | 53 |
| P9 Bearing Results for Alcoa CW67 Sheet Long Transverse Orientation and $e/D=2.0$ | 53 |
| P10 R-Curve Data for Alcoa CW67 Sheet, Specimen 32 and L-T Orientation | 54 |
| P11 R-Curve Data for Alcoa CW67 Sheet, Specimen 33 and L-T Orientation | 55 |
| P12 R-Curve Data for Alcoa CW67 Sheet Specimen 34 and T-L Orientation | 56 |
| P13 R-Curve Data for Alcoa CW67 Sheet, Specimen 35 and T-L Orientation | 57 |
| P14 R-Curve Data Associated with Figures P1 and P2 (Specimen 1) | 59 |
| P15 R-Curve Data Associated with Figures P1 and P2 (Specimen 2) | 60 |
| Q1 Tensile Results for Alcoa CW67 Plate, Longitudinal Orientation | 66 |
| Q2 Tensile Results for Alcoa CW67 Plate, Long Transverse Orientation | 66 |
| Q3 R-Curve Data Associated with Figures Q1 and Q2 (Specimen 1) | 68 |

| <u>TABLE</u> | | <u>PAGE</u> |
|---------------------|---|--------------------|
| Q4 | R-Curve Data Associated with Figures Q1 and Q2 (Specimen 2) | 69 |
| R1 | Tensile Results for Alcoa CW67 Extrusion, Longitudinal Orientation | 71 |
| R2 | Tensile Results for Alcoa CW67 Extrusion, Long Transverse Orientation | 71 |
| R3 | Compression Results for Alcoa CW67 Extrusion, Longitudinal Orientation | 72 |
| R4 | Compression Results for Alcoa CW67 Extrusion, Long Transverse Orientation | 72 |
| R5 | Iosipescu Shear Results for Alcoa CW67 Extrusion, Longitudinal Orientation | 73 |
| R6 | Iosipescu Shear Results for Alcoa CW67 Extrusion, Long Transverse Orientation | 73 |
| R7 | Amsler Double Shear Results for Alcoa CW67 Extrusion L-S Orientation | 74 |
| R8 | Bearing Results for Alcoa CW67 Extrusion, Longitudinal Orientation and $e/D=1.5$ | 75 |
| R9 | Bearing Results for Alcoa CW67 Extrusion, Long Transverse Orientation and $e/D=1.5$ | 75 |
| R10 | Bearing Results for Alcoa CW67 Extrusion, Longitudinal Orientation and $e/D=2.0$ | 76 |
| R11 | Bearing Results for Alcoa CW67 Extrusion, Long Transverse Orientation and $e/D=2.0$ | 76 |
| R12 | Fracture Toughness Results for Alcoa CW67 Extrusion L-T Orientation | 77 |
| R13 | Fracture Toughness Results for Alcoa CW67 Extrusion T-L Orientation | 77 |
| R14 | Fracture Toughness Results for Alcoa CW67 Extrusion S-T Orientation | 78 |
| R15 | Fracture Toughness Results for Alcoa CW67 Extrusion S-L Orientation | 78 |
| S1 | Tensile Results for Alcoa CW67 Forging, Longitudinal Orientation | 101 |
| S2 | Tensile Results for Alcoa CW67 Forging, Long Transverse Orientation | 101 |

| <u>TABLE</u> | | <u>PAGE</u> |
|---------------------|---|--------------------|
| S3 | Tensile Results for Alcoa CW67 Forging, Short Transverse Orientation | 102 |
| S4 | Compression Results for Alcoa CW67 Forging, Longitudinal Orientation | 103 |
| S5 | Compression Results for Alcoa CW67 Forging, Long Transverse Orientation | 103 |
| S6 | Compression Results for Alcoa CW67 Forging Short Transverse Orientation | 104 |
| S7 | Pin Shear Results for Alcoa CW67 Forging, Longitudinal Orientation | 105 |
| S8 | Pin Shear Results for Alcoa CW67 Forging, Long Transverse Orientation | 105 |
| S9 | Bearing Results for Alcoa CW67 Forging | 106 |
| S10 | Fracture Toughness Results for Alcoa CW67 Forging, L-T Orientation | 107 |
| S11 | Fracture Toughness Results for Alcoa CW67 Forging, L-S Orientation | 107 |
| S12 | Fracture Toughness Results for Alcoa CW67 Forging, T-L Orientation | 108 |
| S13 | Fracture Toughness Results for Alcoa CW67 Forging, T-S Orientation | 108 |
| S14 | Fracture Toughness Results for Alcoa CW67 Forging, S-T Orientation | 109 |

PREFACE

This report was prepared by the Materials Engineering Branch (WL/MLSE), Systems Support Division, Materials Directorate, Wright Laboratory, Wright-Patterson Air Force Base, Ohio, under Project 2418, "Metallic Structural Materials," Task 241807, "Systems Support," Work Unit 24180703, "Engineering and Design Data."

The authors would like to thank the participants Lockheed GA, LTV TX, Martin Marietta LA, McDonnell Aircraft Company MO and the Air Force.

SECTION 1

INTRODUCTION

High performance aerospace systems are dependent on materials that are lighter, have improved mechanical properties, and/or offer a cost savings. Aluminum alloys that met these criteria were the newly developed aluminum-lithium alloys and the second generation powder metallurgy alloys.

In 1985, the Air Force along with the aerospace community found it important to investigate the potential of these promising aluminum alloys. A cooperative program was formed by the Wright Laboratory Materials Directorate, Systems Support Division, and a number of aerospace industries. The Air Force would obtain the test material from the producers, compile the test data, and submit reports to the participants. The participants agreed to support the program by performing mechanical property tests which includes tension, compression, bearing, shear, fracture toughness, and fatigue related properties (S/N, da/dn). The Air Force elected to perform spectrum fatigue crack growth testing on most alloys. A list of participants is shown in the following table.

This interim report contains the powder metallurgy (P/M) aluminum alloys: 7064-T74511 extrusion, and 7064-T74 forging produced by Kaiser and CW67 sheet, plate, extrusion, and forging produced by Alcoa. Comparisons to other materials and ranking of materials are generally avoided since each potential application may be based on different evaluation criteria.

TABLE
PARTICIPANTS AND ADVANCED ALUMINUM ALLOYS
IN THE COOPERATIVE TEST PROGRAM

| PARTICIPANTS | ALUMINUM LITHIUM ALLOYS | | | | | | | | | | P/M ALUMINUM ALLOYS | | | | | | | | |
|-----------------------------------|-------------------------|--------------------------|-----------------|-----------------------|---------------------|--------------------------|--------------------|--------------------|------------------------|------------------------|-----------------------|----------------|---------------------------------|-----------------------|------------------|---------------------|--------------------|----------------|--------------|
| | PECHINEY | ALCAN | IncoMAP | ALCOA | REYNOLDS | KAISER | ALCOA | | | | | | | | | | | | |
| | 2091-T3 Sheet (0.063") | 2091-T351 Plate (0.420") | 2091-T6 Forging | 8090-T651 T Extrusion | 8090-T651 Extrusion | 8090-T6771 Plate (1.75") | PM IN905XL Forging | PM AL905XL Forging | 2091-T3 Sheet (0.063") | 2091-T3 Sheet (0.144") | 2091-T8 Plate (0.50") | 8090 Extrusion | Weldable 049 RX815 Plate (0.5") | 7064-T74511 Extrusion | 7064-T74 Forging | CW67 Sheet (0.063") | CW67 Plate (0.40") | CW67 Extrusion | CW67 Forging |
| Air Force WPAFB, OH | x | | | | x | x | x | x | x | x | x | x | x | x | x | | | x | x |
| Army, MA | | | | | | | | | | | | x | x | | | | | | |
| AVCO, TN | | | | | | | | | x | | | | | | | | | | |
| Boeing, WA | x | x | x | x | | | | | | | | | | | | | | | |
| Douglas Aircraft, CA | | | | | | | | x | x | x | x | x | x | | | | | | |
| General Dynamics, CA | x | x | | | | | | | x | x | x | | x | | | | | | |
| General Dynamics, TX | x | x | x | x | | | x | | x | x | x | x | | | | | | | |
| Grumman Aerospace, NY | x | x | | | x | | x | | | | | | | x | x | | | x | x |
| Jet Propulsion, CA | | | | | | | | x | | | | | x | | | | | | |
| Lockheed, CA | x | | x | | | | | x | x | | x | | | | | | | | |
| Lockheed, GA | | x | | | x | | | | x | x | | | | | x | | | x | |
| LTV, TX | x | | x | | | | x | x | x | | | x | | x | x | | x | | |
| Martin Marietta, LA | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | x | x | x | x |
| McDonnell Douglas Astro, CA | | | | | | | | | x | | | | x | | | | | | |
| McDonnell Douglas Helicopter, AR | | | | | | | | x | | | | | | | | | | | |
| McDonnell Douglas Missile Sys, MO | | | | | | | | | | | | | x | | | | | | |
| McDonnell Aircraft, MO | x | | | | | | x | x | x | | | | | | x | x | | x | |
| NASA, VA | | | | | x | | x | x | | | | | x | | | | | | |
| Naval Air Development Center | x | | x | | | | | x | | x | | | | | | | | x | |
| Northrop, CA | x | x | x | | x | x | x | x | x | x | x | x | x | x | | | | | |
| Sikorsky, CT | | | | | | | x | | x | | | | | | x | | x | | x |
| Sundstrand, IL | | | | | | | | | | | | | x | | | | | | |
| Wyman-Gordon | | | | | | | | x | | | | | | | | | | | |

SECTION 2

MATERIALS AND TESTS

The Kaiser P/M aluminum alloys 7064-T74511 1 inch x 4 inch x 48 inch extrusion and 7064-T74 1.6 inch x 4 inch x 18 inch forging were received in December 1986. The Alcoa P/M aluminum alloys were received on various dates: CW67 0.063-inch sheet and 0.4-inch plate April 1989, CW67 1.5 inch x 4.5 inch x 36 inch extrusion August 1987 and CW67 2.5 inch x 6 inch x 18 inch hand forging October 1988.

The 7064 extrusion was tested by LTV, Martin Marietta and the Air Force. Forged 7064 was tested by Lockheed, LTV, Martin Marietta, McDonnell Aircraft Company, and the Air Force. CW67 sheet was tested by Martin Marietta and McDonnell Aircraft Company. Only Martin Marietta tested CW67 plate. LTV, McDonnell Aircraft Company and the Air Force tested the CW67 Extrusion material. CW67 forging was tested by Martin Marietta and the Air Force.

Mechanical properties (tension, compression, shear, bearing and fracture toughness), fatigue, and constant amplitude fatigue crack growth tests were generated according to ASTM standards, unless otherwise specified.

Spectrum fatigue crack growth rate tests were performed by the Air Force using FALSTAFF (a severe fatigue environment) and Mini-TWIST (a moderately intense fatigue environment) spectrums.

SECTION 3

PRESENTATION

Each participant compiled a data package which contained the data they generated. Some of these data packages contain discussions, and in other cases, only the data were provided. The tensile, compression, shear and bearing are in tabular form. Fatigue and toughness values are shown in tabular and graphical form. Fatigue crack growth and spectrum fatigue crack growth are in graphical form.

SECTION 4

RESULTS AND DISCUSSION

The data generated by the participants on the 7064 extrusion, 7064 forging, CW67 sheet, CW67 plate, CW67 extrusion and CW67 forging are in the appendices. The table lists the P/M aluminum alloy, form, and the appendix where the data can be found in the following table.

TABLE
CONTENTS OF APPENDICES

| P/M Aluminum Alloy | Form | Appendix |
|--------------------|--------------|----------|
| 7064-T74511 | Extrusion | N |
| 7064-T74 | Forging | O |
| CW67 | 0.063" Sheet | P |
| CW67 | 0.40" Plate | Q |
| CW67 | Extrusion | R |
| CW67 | Forging | S |

SECTION 5

CONCLUSIONS

Five aerospace laboratories participated in generating data on the 7064 and CW67 P/M aluminum alloys for the cooperative test program. These data combined with previous interim reports on the Air Force/Industry Cooperative Test Program on Advance Aluminum Alloys provide an extensive data base on advanced aluminum alloys.

APPENDIX N

**7064-T74511 EXTRUSION
1"X4"X48"**

TABLE N1
TENSILE RESULTS AT t/2 LOCATION FOR
KAISER 7064-T74511 EXTRUSION

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | MODULUS (MSI) |
|----------------------------------|-----------------------------|--------------------|-------------------------------|----------------------------|--------------|-----------|------------------|
| LTV | RT | LONG | 85.8 | 79.4 | 12.2 | 21.6 | 10.0 |
| | | | 87.5 | 81.7 | 12.3 | 19.3 | 9.7 |
| | | | 87.7 | 82.2 | 14.3 | 22.3 | 10.3 |
| AIR FORCE | RT | LONG | 82.2 | 75.8 | 10.5 | 18.0 | |
| | | | 80.7 | 73.9 | 11.3 | 24.3 | |
| | | | 81.2 | 74.7 | 12.0 | 25.6 | |
| MARTIN MARIETTA, LOUISIANA | RT | LONG | 91.6 | 86.5 | 18.0 | 27.5 | 9.8 |
| | | | 90.5 | 85.3 | 20.0 | 30.6 | 9.4 |
| | | | 90.2 | 85.0 | 19.0 | 31.0 | 9.7 |
| | | AVERAGE | 86.4 | 80.5 | 14.4 | 24.5 | 9.8 |
| | | STANDARD DEVIATION | 4.2 | 4.8 | 3.6 | 4.6 | 0.3 |

TABLE N2
TENSILE RESULTS AT t/2 LOCATION FOR
KAISER 7064-T74511 EXTRUSION

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | MODULUS (MSI) |
|----------------------------------|-----------------------------|--------------------|-------------------------------|----------------------------|--------------|-----------|------------------|
| LTV | RT | L TRANS | 83.0 | 76.6 | 9.0 | 11.8 | 9.2 |
| | | | 85.3 | 79.6 | 8.5 | 19.1 | 10.4 |
| | | | 85.5 | 80.2 | 11.0 | 22.7 | 10.4 |
| AIR FORCE | RT | L TRANS | 79.2 | 72.8 | 10.0 | 21.6 | |
| | | | 78.3 | 72.0 | 10.7 | 25.6 | |
| | | | 79.1 | 72.6 | 11.3 | 27.8 | |
| MARTIN MARIETTA, LOUISIANA | RT | L TRANS | 88.8 | 82.7 | 8.0 | 7.8 | 10.7 |
| | | | 89.2 | 83.2 | 9.0 | 2.0 | 10.1 |
| | | | 88.0 | 82.7 | 10.0 | 16.1 | 9.7 |
| | | AVERAGE | 84.0 | 78.0 | 9.7 | 17.2 | 10.1 |
| | | STANDARD DEVIATION | 4.3 | 4.6 | 1.2 | 8.6 | 0.5 |

TABLE N3
COMPRESSION RESULTS AT t/2 LOCATION FOR
KAISER 7064-T74511 EXTRUSION

| COMPANY | TEST TEMPERATURE (DEGREES F) | ORIENTATION | COMPRESSIVE YIELD STRENGTH (KSI) | COMPRESSIVE MODULUS (MSI) |
|----------------------------------|------------------------------------|--------------------|--|---------------------------------|
| LTV | RT | LONG | 97.4 79.8 83.0 | 14.8 10.3 11.8 |
| AIR FORCE | RT | LONG | 83.3 81.6 82.5 | |
| MARTIN MARIETTA, LOUISIANA | RT | LONG | 87.1 86.0 86.9 | 11.1 11.1 11.1 |
| | | AVERAGE | 85.3 | 11.7 |
| | | STANDARD DEVIATION | 5.2 | 1.6 |

TABLE N4
COMPRESSION RESULTS AT t/2 LOCATION FOR
KAISER 7064-T74511 EXTRUSION

| COMPANY | TEST TEMPERATURE (DEGREES F) | ORIENTATION | COMPRESSIVE YIELD STRENGTH (KSI) | COMPRESSIVE MODULUS (MSI) |
|----------------------------------|------------------------------------|--------------------|--|---------------------------------|
| LTV | RT | L TRANS | 82.7 82.9 82.8 | 10.8 11.8 11.2 |
| AIR FORCE | RT | L TRANS | 83.3 81.8 84.1 | |
| MARTIN MARIETTA, LOUISIANA | RT | L TRANS | 87.3 86.1 86.6 | 11.4 11.3 11.9 |
| | | AVERAGE | 84.2 | 11.4 |
| | | STANDARD DEVIATION | 2.0 | 0.4 |

TABLE N5
IOSIPESCU SHEAR RESULTS FOR
KAISER 7064-T74511 EXTRUSION

| COMPANY | ORIENTATION | ULTIMATE STRENGTH (KSI) |
|---------|--------------------|-------------------------------|
| <hr/> | | |
| LTV | LONG | 49.7 |
| | | 51.0 |
| | | 50.9 |
| | AVERAGE | 50.5 |
| | STANDARD DEVIATION | 0.7 |

TABLE N6
IOSIPESCU SHEAR RESULTS FOR
KAISER 7064-T74511 EXTRUSION

| COMPANY | ORIENTATION | ULTIMATE STRENGTH (KSI) |
|---------|--------------------|-------------------------------|
| <hr/> | | |
| LTV | L TRANS | 50.4 |
| | | 49.8 |
| | | 50.2 |
| | AVERAGE | 50.1 |
| | STANDARD DEVIATION | 0.3 |

TABLE N7
BEARING RESULTS FOR KAISER
7064-T74511 EXTRUSION

| COMPANY | ORIENTATION | e/D | BEARING ULT. STR. (KSI) | BEARING YIELD STR. (KSI) |
|---------|-------------|--------------------|-------------------------------|--------------------------------|
| LTV | LONG | 1.5 | 124.5 | 93.9 |
| | | | 134.4 | 111.9 |
| | | | 129.8 | 108.2 |
| | | | | |
| | | AVERAGE | 129.6 | 104.7 |
| | | STANDARD DEVIATION | 5.0 | 9.5 |

TABLE N8
BEARING RESULTS FOR KAISER
7064-T74511 EXTRUSION

| COMPANY | ORIENTATION | e/D | BEARING ULT. STR. (KSI) | BEARING YIELD STR. (KSI) |
|-----------|-------------|--------------------|-------------------------------|--------------------------------|
| LTV | LONG | 2.0 | 159.5 169.5 160.8 | 122.7 122.2 117.0 |
| AIR FORCE | LONG | 2.0 | 163.5 166.7 162.3 | 139.5 125.3 120.0 |
| | | AVERAGE | 163.7 | 124.5 |
| | | STANDARD DEVIATION | 3.8 | 7.9 |

TABLE N9
BEARING RESULTS FOR KAISER
7064-T74511 EXTRUSION

| COMPANY | ORIENTATION | e/D | BEARING ULT. STR. (KSI) | BEARING YIELD STR. (KSI) |
|-----------|-------------|--------------------|-------------------------------|--------------------------------|
| AIR FORCE | L TRANS | 2.0 | 164.2 159.3 163.5 | 123.8 114.7 115.6 |
| | | AVERAGE | 162.3 | 118.0 |
| | | STANDARD DEVIATION | 2.7 | 5.0 |

TABLE N10
FRACTURE TOUGHNESS RESULTS FOR
KAISER 7064-T74511 EXTRUSION

| COMPANY | ORIENTATION | KIC | | Kq | COMMENT |
|----------------------------------|--------------------|--------------------------|--------------------------|------|---------|
| | | (KSI IN ^{0.5}) | (KSI IN ^{0.5}) | | |
| LTV | L-T | | | 32.6 | (1) |
| | | | | 33.5 | (1) |
| | | | | 29.6 | (1) |
| AIR FORCE | L-T | | | 29.5 | (2) |
| | | | | 27.9 | (2) |
| | | | | 28.8 | (2) |
| MARTIN MARIETTA, LOUISIANA | L-T | 24.2 | | | VALID |
| | | | | 26.3 | (3) |
| | | | | 25.2 | (3) |
| | AVERAGE | 24.2 | | 29.2 | |
| | STANDARD DEVIATION | | | 2.8 | |

(1): INVALID DUE TO TEST SPECIMEN FRACTURE SURFACE
VIOLATED KIC REQUIREMENTS

(2): INVALID DUE TO SURFACE CRACK LENGTH/AVERAGE CRACK LENGTH > 1.1

(3): INVALID DUE TO CRACK SIZE DID NOT EXCEED PLASTIC ZONE SIZE

TABLE N11
FRACTURE TOUGHNESS RESULTS FOR
KAISER 7064-T74511 EXTRUSION

| COMPANY | ORIENTATION | KIC (KSI IN ^{0.5}) | K _q (KSI IN ^{0.5}) | COMMENT |
|----------------------------------|--------------------|---------------------------------|--|---------|
| LTV | T-L | 24.6 | | VALID |
| | | 25.0 | | VALID |
| | | 25.2 | | VALID |
| AIR FORCE | T-L | 23.5 | | VALID |
| | | 24.1 | | VALID |
| | | 23.8 | | VALID |
| MARTIN MARIETTA, LOUISIANA | T-L | | 10.2 | (1) |
| | | 17.1 | | |
| | | 17.1 | | |
| | AVERAGE | 22.6 | 10.2 | |
| | STANDARD DEVIATION | 3.4 | | |

(1): INVALID DUE TO PRECRACKING LOADS WERE TOO HIGH

TABLE N12
FATIGUE RESULTS WITH $K_t=1.0$ AND $R=0.1$ FOR
KAISER 7064-T74511 EXTRUSION

| COMPANY | ORIENTATION | LIMIT STRESS (KSI) | CYCLES TO FAILURE |
|---------|-------------|--------------------------|----------------------|
| <hr/> | | | |
| LTV | LONG | 65.6 | 13,900 |
| | | 65.0 | 1,800 |
| | | 56.6 | 23,400 |
| | | 47.9 | 49,900 |
| | | 47.9 | 75,700 |
| | | 47.8 | 318,100 # |
| | | 45.0 | 6,500 |
| | | 43.5 | 2,000,000 * |
| | | 39.4 | 38,500 |
| | | 39.1 | 93,100 # |
| | | 37.0 | 193,900 |
| | | 35.0 | 113,000 |
| | | 30.0 | 800,000 * |
| | | 25.2 | 2,300,000 * |

(*): INDICATES A RUN OUT TEST

(#): INDICATES SPECIMEN FAILED IN THE THREADS

TABLE N13
FATIGUE RESULTS WITH $K_t=3.0$ AND $R=0.1$ FOR
KAISER 7064-T74511 EXTRUSION

| COMPANY | ORIENTATION | LIMIT STRESS (KSI) | CYCLES TO FAILURE |
|---------|-------------|--------------------------|----------------------|
| LTV | LONG | 43.5 | 5,100 |
| | | 34.8 | 10,800 |
| | | 32.6 | 19,700 |
| | | 31.3 | 23,500 |
| | | 30.5 | 66,200 |
| | | 28.3 | 39,300 |
| | | 26.1 | 56,700 |
| | | 26.1 | 40,400 |
| | | 24.4 | 72,000 |
| | | 23.9 | 3,000,000 * |
| | | 23.5 | 1,998,100 |
| | | 21.8 | 2,000,000 * |
| | | 21.7 | 3,000,000 * |
| | | 20.0 | 2,000,000 * |
| | | 17.4 | 3,000,000 * |

(*): INDICATES A RUN-OUT TEST

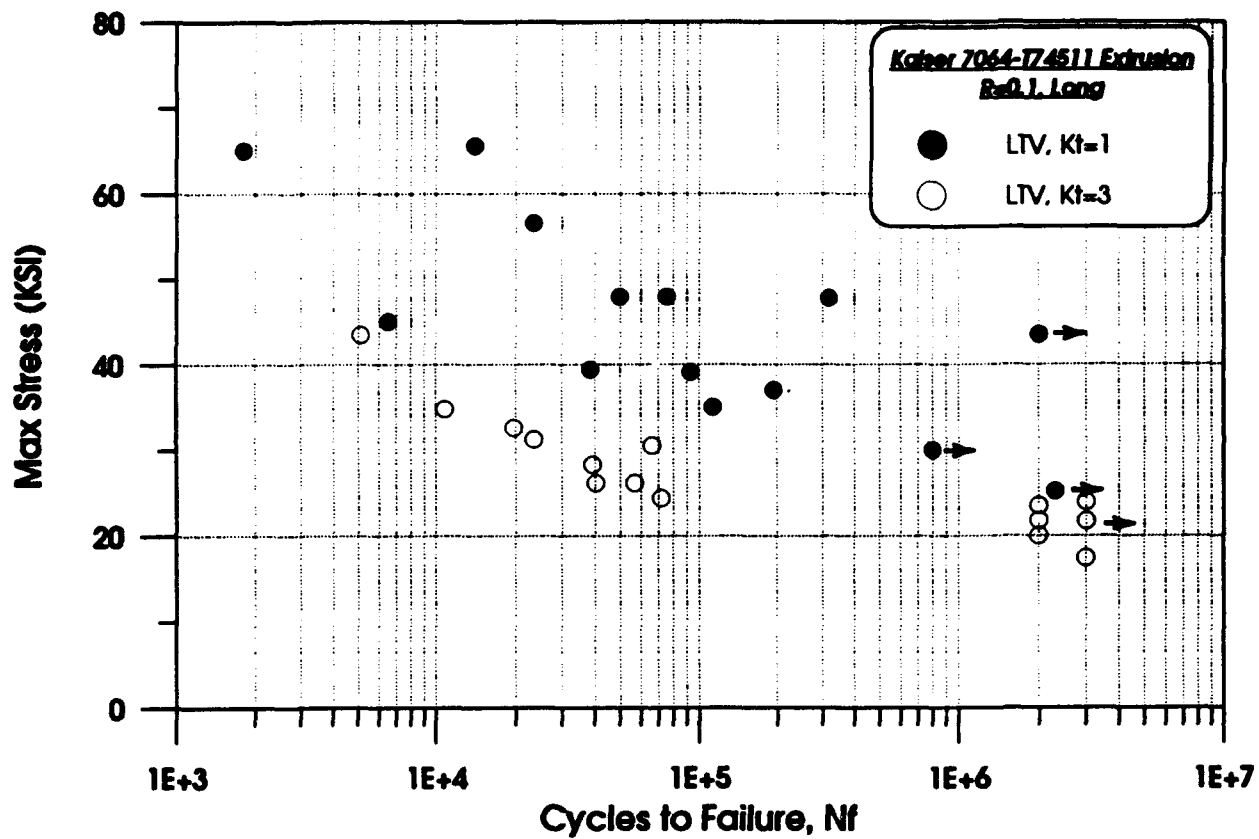


FIGURE N1. FATIGUE RESULTS FOR 7064-T74511 EXTRUSION (LONGITUDINAL ORIENTATION). LTV.

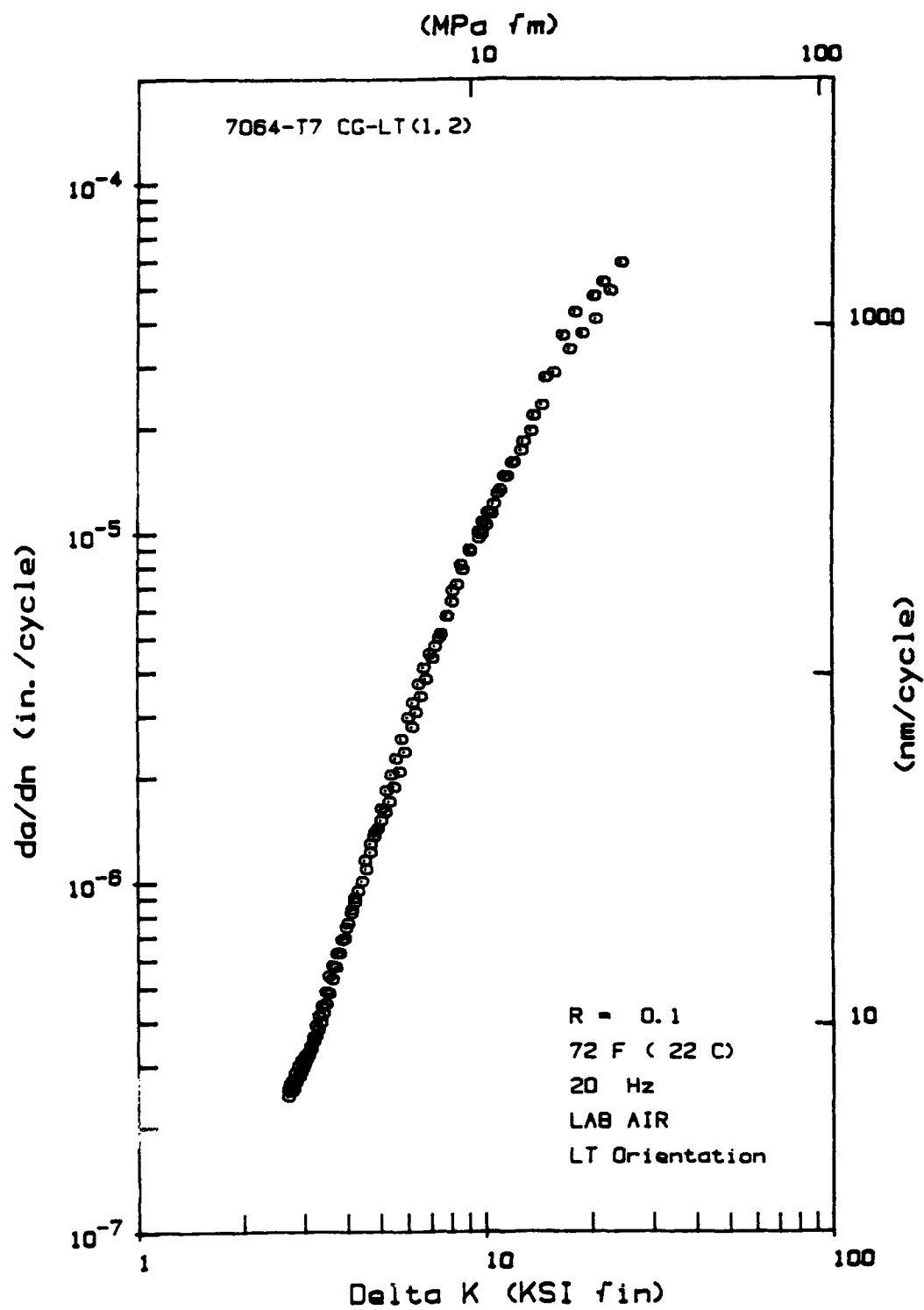


FIGURE N2. FATIGUE CRACK GROWTH RATE DATA for Two 7064-T74511 Extrusion Specimens. (L-T ORIENTATION). AIR FORCE.

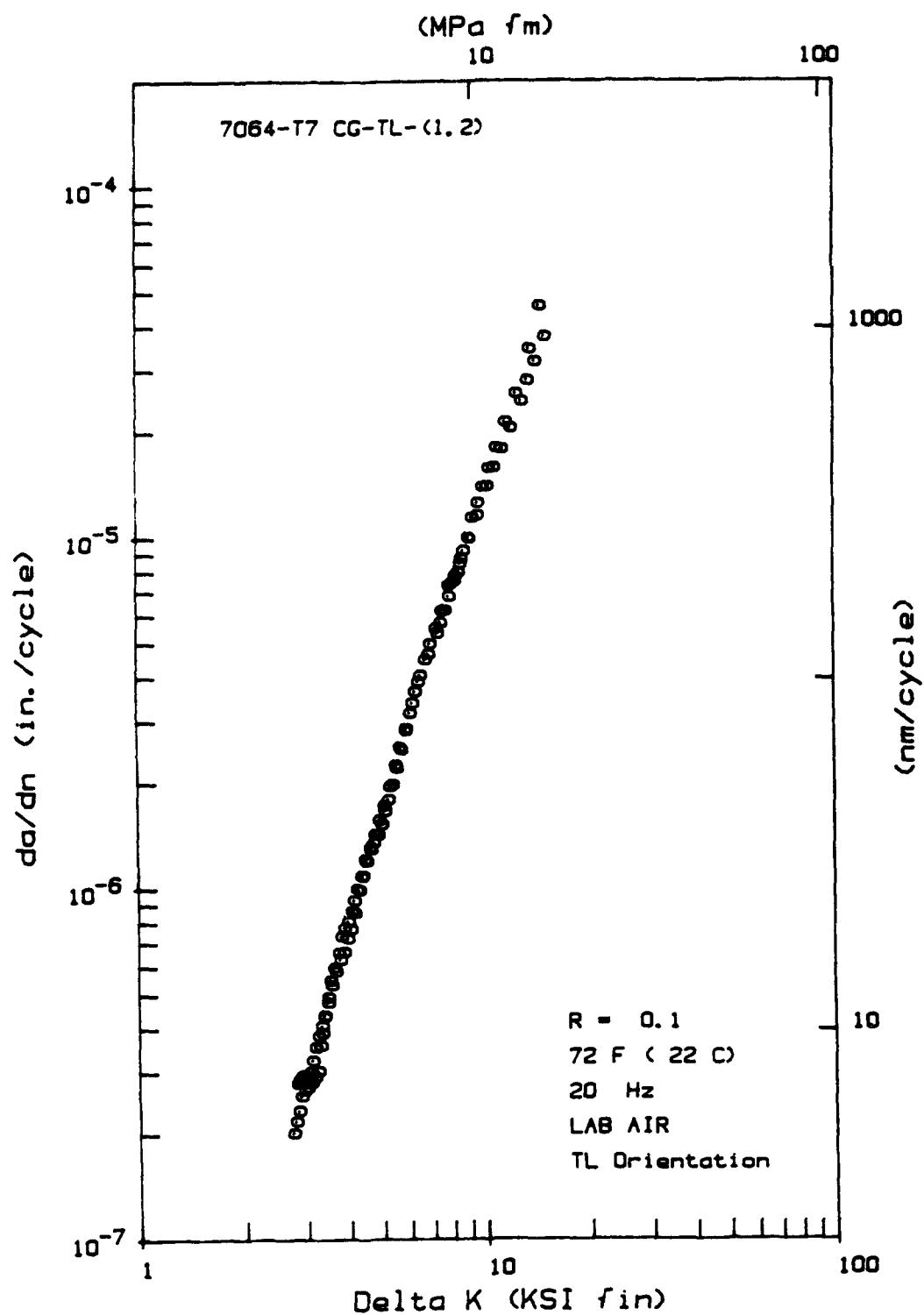


FIGURE N3. FATIGUE CRACK GROWTH RATE DATA for Two 7064-T74511 Extrusion Specimens. (T-L ORIENTATION). AIR FORCE.

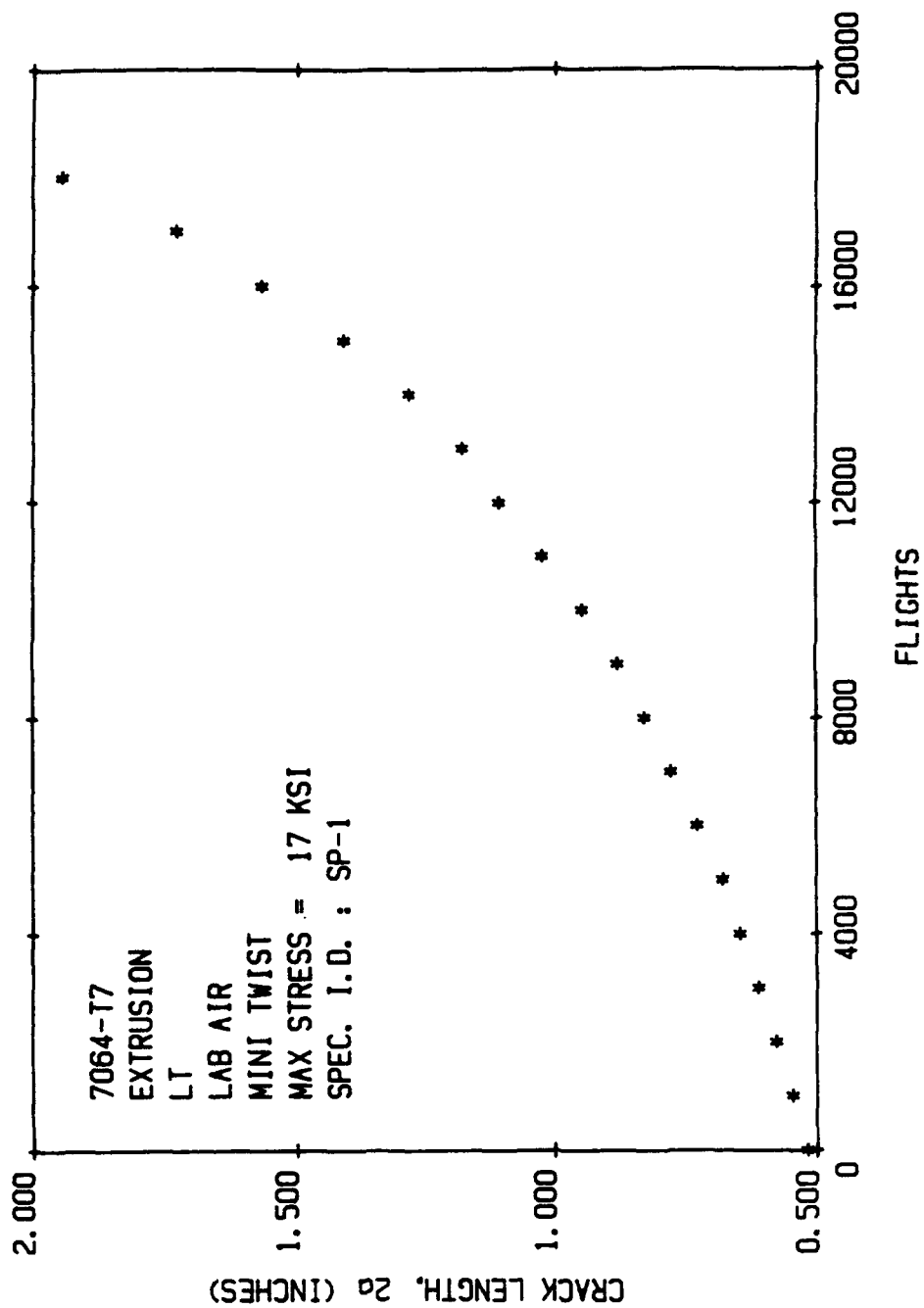


FIGURE N4. Mini-TWIST Spectrum Fatigue Crack Length vs Flights Data for 7064-T74511 Extrusion.
Air Force.

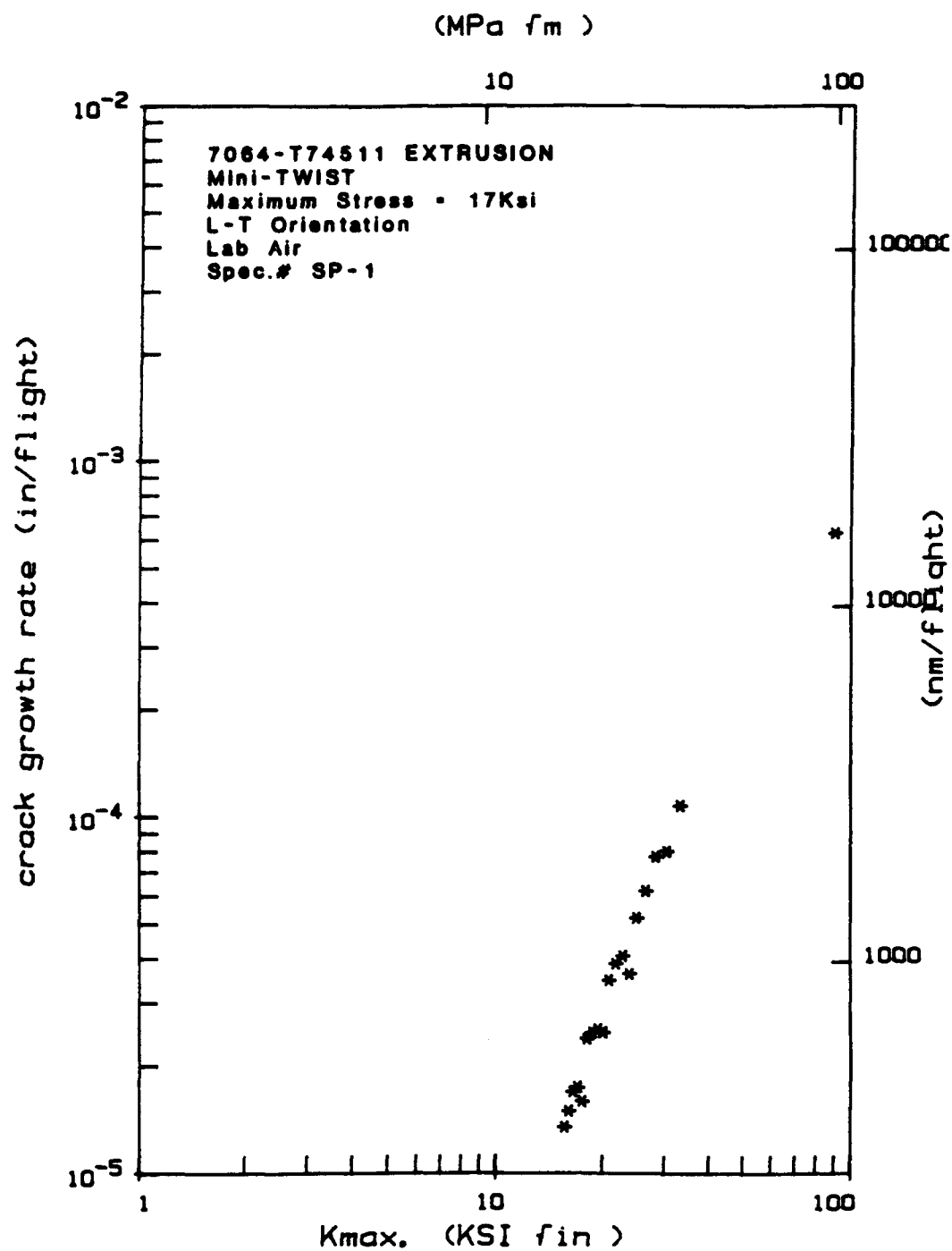


FIGURE N5. Mini-TWIST Spectrum Fatigue Crack Growth Rate Data for 7064-T74511 Extrusion. Air Force.

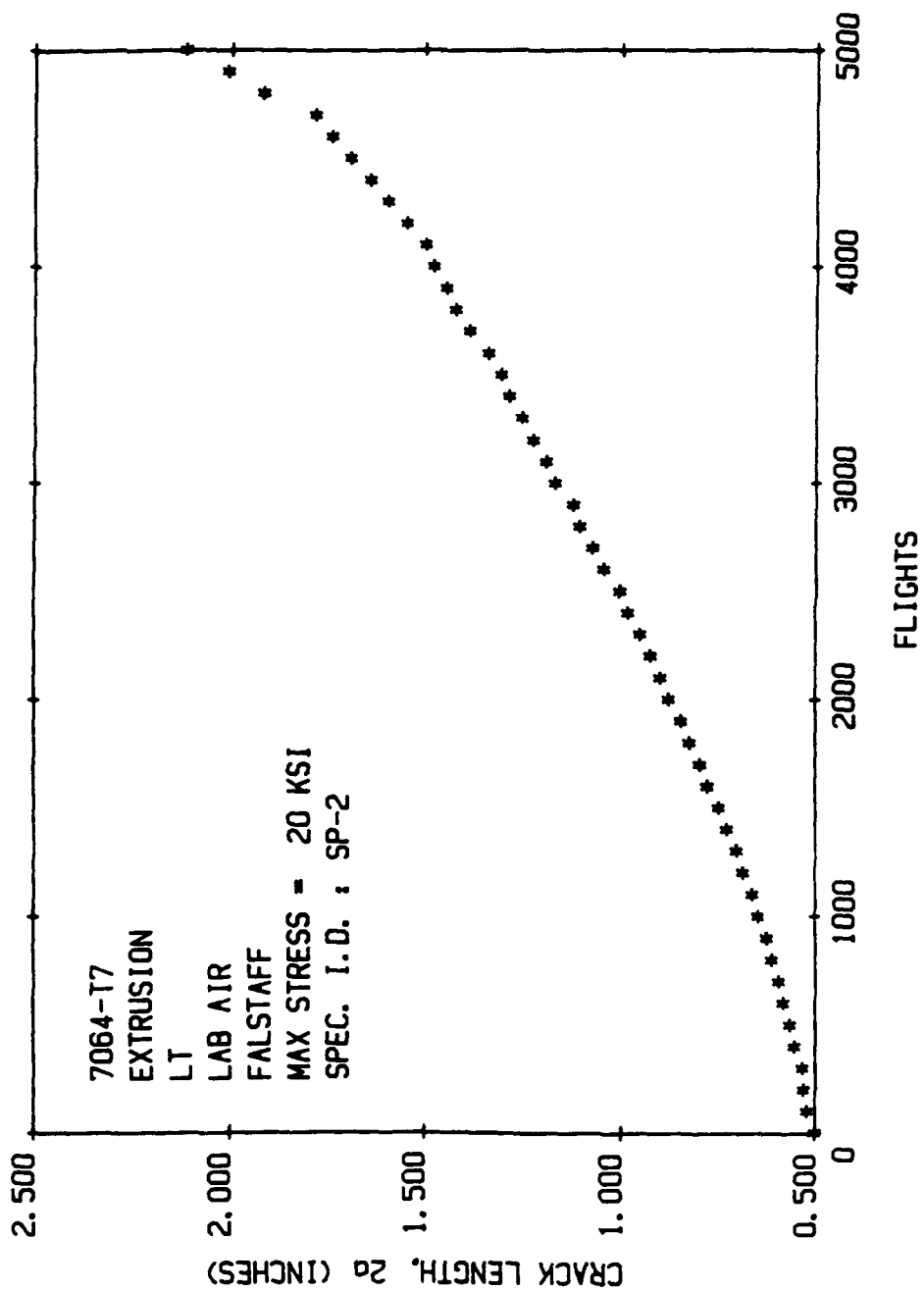


FIGURE N6. FALSTAFF Spectrum Fatigue Crack Length vs Flights Data for 7064-T74511 Extrusion.
Air Force.

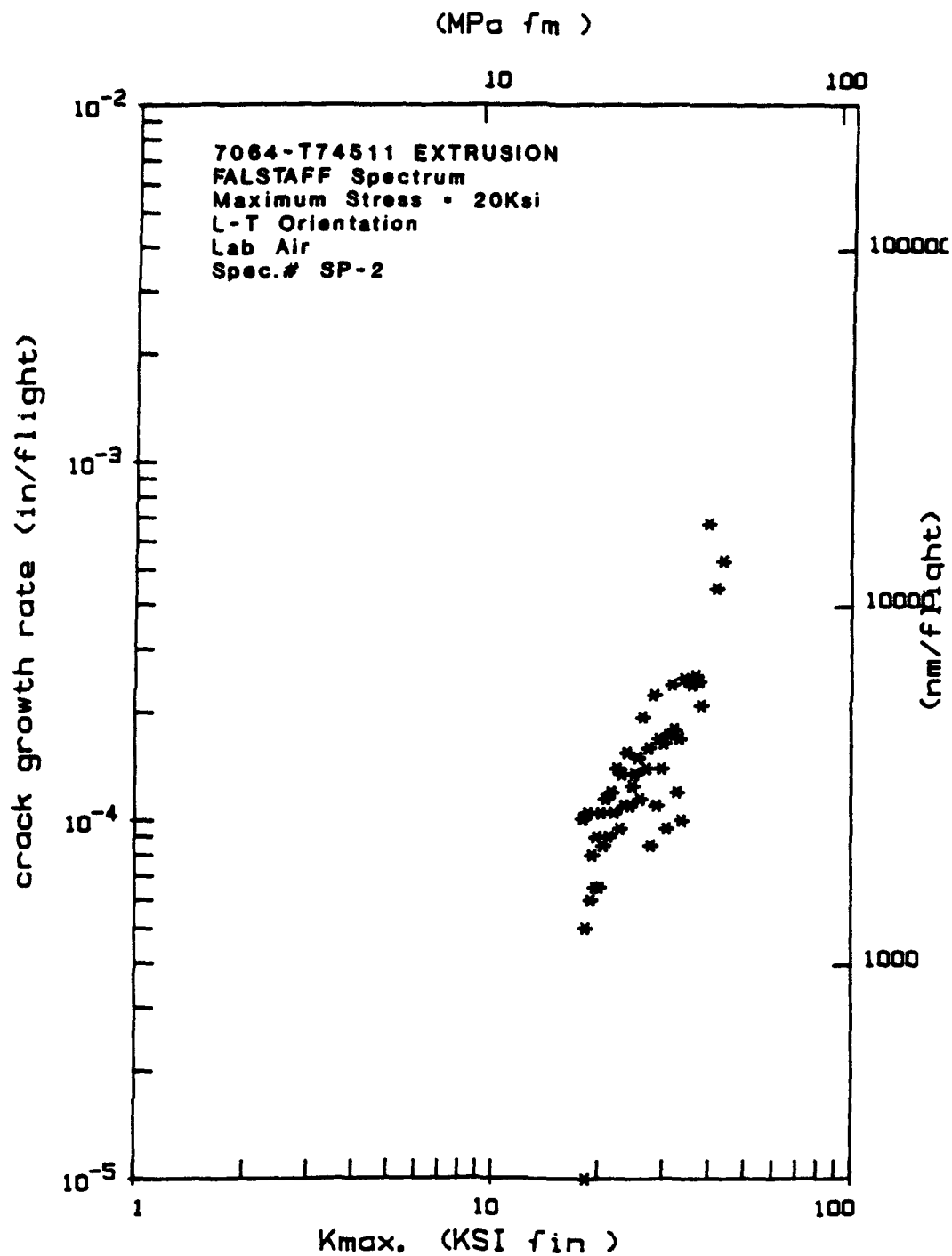


FIGURE N7. FALSTAFF Spectrum Fatigue Crack Growth Rate Data for 7064-T74511 Extrusion. Air Force.

APPENDIX O
7064-T74 HAND FORGING
1.6"X4"X18"

TABLE 01
TENSILE RESULTS AT t/2 LOCATION FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | MODULUS (MSI) |
|----------------------------------|-----------------------------|------------------|-------------------------------|----------------------------|--------------|-----------|------------------|
| MCAIR, ST. LOUIS | RT | LONG | 80.0 | 74.0 | 13.0 | | |
| | | | 80.0 | 73.0 | 14.0 | | |
| | | | 81.5 | 75.0 | 11.0 | | |
| | | | 80.5 | 74.0 | 13.0 | | |
| LOCKHEED, GEORGIA | RT | LONG | 77.2 | 69.7 | | | 9.9 |
| | | | 81.9 | 75.0 | | | 11.2 |
| | | | 81.0 | 75.2 | | | 10.5 |
| | | | 84.9 | 79.0 | | | 10.6 |
| | | | 81.5 | 74.7 | | | 10.2 |
| | | | 81.1 | 74.1 | | | 10.1 |
| | | | 80.0 | 74.0 | | | 10.1 |
| | | | 84.1 | 78.4 | | | 9.9 |
| | | | 80.6 | 73.6 | | | 10.3 |
| | | | 80.5 | 74.3 | | | 10.1 |
| MARTIN MARIETTA, LOUISIANA | RT | LONG | 79.5 | 71.4 | 5.0 | 41.6 | 10.1 |
| | | | 79.4 | 70.9 | 12.0 | 44.0 | 10.2 |
| | | | 78.6 | 70.6 | 14.0 | 37.9 | 10.1 |
| LTV | RT | LONG | 80.6 | 74.3 | 13.3 | 32.4 | 9.4 |
| | | | 79.1 | 72.6 | 13.7 | 29.8 | 9.5 |
| | | | 78.7 | 71.7 | 15.4 | 38.9 | 9.5 |
| | | | 82.0 | 75.9 | 10.6 | 31.0 | 9.7 |
| AVERAGE | | | 80.6 | 73.9 | 12.3 | 36.5 | 10.1 |
| STANDARD DEVIATION | | | 1.8 | 2.3 | 2.8 | 5.5 | 0.4 |

TABLE 02
TENSILE RESULTS AT t/2 LOCATION FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | MODULUS (MSI) |
|----------------------------------|-----------------------------|------------------|-------------------------------|----------------------------|--------------|-----------|------------------|
| MCAIR, ST. LOUIS | RT | L TRANS | 80.0 | 72.0 | 8.0 | | |
| | | | 80.0 | 72.5 | 9.0 | | |
| | | | 80.5 | 73.0 | 8.0 | | |
| | | | 80.0 | 72.5 | 8.0 | | |
| LOCKHEED, GEORGIA | RT | L TRANS | 83.0 | 77.1 | | | 10.8 |
| | | | 80.2 | 73.3 | | | 9.6 |
| | | | 80.5 | 73.7 | | | 9.9 |
| | | | 78.9 | 72.9 | | | 10.0 |
| | | | 79.9 | 73.0 | | | 10.7 |
| | | | 79.9 | 72.5 | | | 9.7 |
| | | | 78.6 | 71.8 | | | 10.6 |
| | | | 79.8 | 71.3 | | | 10.6 |
| | | | 78.0 | 71.4 | | | 10.2 |
| 78.9 | 70.6 | | | 10.4 | | | |
| MARTIN MARIETTA, LOUISIANA | RT | L TRANS | 78.5 | 70.0 | 6.0 | 6.1 | 10.0 |
| | | | 79.2 | 71.3 | 8.0 | 10.2 | 10.0 |
| | | | 77.5 | 69.1 | 13.0 | 32.7 | 10.0 |
| LTV | RT | L TRANS | 77.8 | 70.9 | 8.0 | 15.3 | 9.5 |
| | | | 78.1 | 70.6 | 10.0 | 19.3 | 9.7 |
| | | | 77.8 | 68.8 | 8.0 | 11.7 | 10.0 |
| | | | 77.2 | 68.7 | 7.0 | 9.7 | 10.3 |
| AVERAGE | | | 79.3 | 71.8 | 8.5 | 15.0 | 10.1 |
| STANDARD DEVIATION | | | 1.3 | 1.9 | 1.8 | 8.9 | 0.4 |

TABLE 03
TENSILE RESULTS AT t/2 LOCATION FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | MODULUS (MSI) |
|---------------------|-----------------------------|--------------------|-------------------------------|----------------------------|--------------|-----------|------------------|
| MCAIR, ST. LOUIS | RT | S TRANS | 82.5 | 77.0 | 10.0 | | |
| | | | 83.0 | 76.5 | 6.0 | | |
| | | | 81.5 | 75.0 | 6.0 | | |
| | | | 82.0 | 76.0 | 7.0 | | |
| | | AVERAGE | 82.3 | 76.1 | 7.3 | | |
| | | STANDARD DEVIATION | 0.6 | 0.9 | 1.9 | | |

TABLE 04
COMPRESSION RESULTS AT t/2 LOCATION FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | TEST TEMPERATURE (DEGREES F) | ORIENTATION | COMPRESSIVE YIELD STRENGTH (KSI) | COMPRESSIVE MODULUS (MSI) |
|----------------------------------|------------------------------------|--------------------|--|---------------------------------|
| MCAIR, ST. LOUIS | RT | LONG | 75.5 | 11.2 |
| | | | 77.5 | 11.5 |
| | | | 75.0 | 10.8 |
| LOCKHEED, GEORGIA | RT | LONG | 76.6 | 10.6 |
| | | | 78.0 | |
| | | | 83.4 | 10.4 |
| | | | 79.9 | 10.6 |
| | | | 83.5 | |
| | | | 78.5 | |
| | | | 78.1 | 10.5 |
| MARTIN MARIETTA, LOUISIANA | RT | LONG | 76.4 | 11.0 |
| | | | 77.2 | 11.0 |
| | | | 75.3 | 10.9 |
| LTV | RT | LONG | 80.4 | 11.5 |
| | | | 77.7 | 11.4 |
| | | | 76.4 | 12.5 |
| | | | 79.6 | 11.8 |
| | | AVERAGE | 78.2 | 11.1 |
| | | STANDARD DEVIATION | 2.5 | 0.6 |

TABLE 05
COMPRESSION RESULTS AT t/2 LOCATION FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | TEST TEMPERATURE (DEGREES F) | ORIENTATION | COMPRESSIVE YIELD STRENGTH (KSI) | COMPRESSIVE MODULUS (MSI) |
|----------------------------------|------------------------------------|-------------|--|---------------------------------|
| MCAIR, ST. LOUIS | RT | L TRANS | 75.0 | 11.2 |
| | | | 76.5 | 11.8 |
| | | | 76.0 | 11.9 |
| LOCKHEED, GEORGIA | RT | L TRANS | 72.9 | |
| | | | 80.5 | |
| | | | 75.3 | 11.2 |
| | | | 78.3 | 11.3 |
| | | | 77.7 | 11.1 |
| | | | 73.8 | 9.8 |
| MARTIN MARIETTA, LOUISIANA | RT | L TRANS | 72.0 | 9.7 |
| | | | 76.4 | 11.2 |
| | | | 76.1 | 11.1 |
| LTV | RT | L TRANS | 76.1 | 11.1 |
| | | | 77.9 | 11.1 |
| | | | 76.8 | 12.0 |
| | | | 78.7 | 11.8 |
| | | | 74.9 | 11.7 |
| AVERAGE | | | 76.2 | 11.2 |
| STANDARD DEVIATION | | | 2.1 | 0.7 |

TABLE 06
SLOTTED SHEAR RESULTS FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | ULTIMATE STRENGTH (KSI) |
|---------------------|--------------------|-------------------------------|
| <hr/> | | |
| MCAIR, ST. LOUIS | LONG | 53.5 |
| | | 47.5 |
| | | 46.5 |
| | AVERAGE | 49.2 |
| | STANDARD DEVIATION | 3.8 |

TABLE 07
AMSLER DOUBLE SHEAR RESULTS FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | ULTIMATE STRENGTH (KSI) |
|----------------------|--------------------|-------------------------------|
| <hr/> | | |
| LOCKHEED, GEORGIA | L-T | 50.0 |
| | | 51.8 |
| | | 50.4 |
| | AVERAGE | 50.7 |
| | STANDARD DEVIATION | 0.9 |

TABLE 08
IOSIPESCU SHEAR RESULTS FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | ULTIMATE STRENGTH (KSI) |
|---------|--------------------|-------------------------------|
| LTV | LONG | 50.5 |
| | | 52.5 |
| | | 48.0 |
| | | 48.9 |
| | | 51.5 |
| | | 51.3 |
| | | 51.7 |
| | | 50.4 |
| | AVERAGE | 50.6 |
| | STANDARD DEVIATION | 1.5 |

TABLE 09
IOSIPESCU SHEAR RESULTS FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | ULTIMATE STRENGTH (KSI) |
|---------|--------------------|-------------------------------|
| LTV | L TRANS | 50.2 |
| | | 51.3 |
| | | 51.2 |
| | | 52.7 |
| | | 49.5 |
| | | 53.7 |
| | | 51.8 |
| | AVERAGE | 51.5 |
| | STANDARD DEVIATION | 1.4 |

TABLE 010
BEARING RESULTS FOR KAISER
7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | e/D | BEARING ULT. STR. (KSI) | BEARING YIELD STR. (KSI) |
|----------------------|-------------|-----|-------------------------------|--------------------------------|
| LOCKHEED, GEORGIA | LONG | 1.5 | 137.0 | 116.0 |
| | | | 115.0 | 105.0 |
| | | | 139.0 | 114.0 |
| LTV | LONG | 1.5 | 132.8 | 112.4 |
| | | | 132.4 | 112.1 |
| | | | 137.7 | 115.9 |
| AVERAGE | | | 132.3 | 112.6 |
| STANDARD DEVIATION | | | 8.9 | 4.1 |

TABLE 011
BEARING RESULTS FOR KAISER
7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | e/D | BEARING ULT. STR. (KSI) | BEARING YIELD STR. (KSI) | | |
|---------|-------------|-----|-------------------------------|--------------------------------|-------|-------|
| LTV | L TRANS | 1.5 | 134.3 | 116.6 | | |
| | | | 135.2 | 114.7 | | |
| | | | 139.1 | 116.5 | | |
| | | | 138.5 | 117.1 | | |
| | | | AVERAGE | | 136.8 | 116.2 |
| | | | STANDARD DEVIATION | | 2.4 | 1.1 |

TABLE 012
BEARING RESULTS FOR KAISER
7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | e/D | BEARING ULT. STR. (KSI) | BEARING YIELD STR. (KSI) |
|----------------------|-------------|-----|-------------------------------|--------------------------------|
| MCAIR, ST. LOUIS | LONG | 2.0 | 148.0 149.0 143.0 | 117.0 112.0 |
| LOCKHEED, GEORGIA | LONG | 2.0 | 168.0 169.0 170.0 | 135.0 123.0 126.0 |
| LTV | LONG | 2.0 | 165.1 170.6 176.1 | 131.9 143.1 137.5 |
| AVERAGE | | | 162.1 | 128.2 |
| STANDARD DEVIATION | | | 12.0 | 10.6 |

TABLE 013
BEARING RESULTS FOR KAISER
7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | e/D | BEARING ULT. STR. (KSI) | BEARING YIELD STR. (KSI) |
|---------------------|-------------|-----|----------------------------------|----------------------------------|
| MCAIR, ST. LOUIS | L TRANS | 2.0 | 149.0 149.0 151.0 | 119.0 116.0 119.0 |
| LTV | L TRANS | 2.0 | 173.0 172.1 171.8 168.1 | 135.9 134.6 135.0 142.8 |
| AVERAGE | | | 162.0 | 128.9 |
| STANDARD DEVIATION | | | 11.7 | 10.6 |

TABLE 014
FRACTURE TOUGHNESS RESULTS FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | KIC (KSI IN ^{-0.5}) | K _q (KSI IN ^{-0.5}) | COMMENT |
|----------------------------------|--------------------|----------------------------------|---|---------------------------|
| MCAIR, ST. LOUIS | L-T | 24.1 27.5 | | VALID VALID |
| LOCKHEED, GEORGIA | L-T | 26.0 29.0 | | VALID VALID |
| MARTIN MARIETTA, LOUISIANA | L-T | | 27.2 23.6 | (1) (1) |
| LTV | L-T | | 24.1 26.4 29.4 | (2) (3) (2) (3) (2) |
| | AVERAGE | 26.7 | 26.1 | |
| | STANDARD DEVIATION | 2.1 | 2.4 | |

- (1): INVALID DUE TO $a/W=0.552 > 0.55$
 (2): INVALID DUE TO TEST SPECIMEN FRACTURE SURFACE
 VIOLATED KIC REQUIREMENTS
 (3): INVALID DUE TO $K_{max} \text{ PRECRACK} > 0.6 K_q$

TABLE 015
FRACTURE TOUGHNESS RESULTS FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | K _{IC} (KSI IN ^{-0.5}) | K _q (KSI IN ^{-0.5}) | COMMENT |
|----------------------------------|--------------------|--|---|----------------|
| MCAIR, ST. LOUIS | T-L | 17.8 17.0 | | VALID VALID |
| MARTIN MARIETTA, LOUISIANA | T-L | | 18.7 | (1) |
| LTV | T-L | | 30.2 21.1 | (2) (3) |
| | | 27.9 | | VALID |
| | AVERAGE | 20.9 | 23.3 | |
| | STANDARD DEVIATION | 6.1 | 6.1 | |

- (1): INVALID DUE TO $a/W=0.552 > 0.55$
 (2): INVALID DUE TO TEST SPECIMEN FRACTURE SURFACE
 VIOLATED K_{IC} REQUIREMENTS
 (3): INVALID DUE TO $K_{max} \text{ PRECRACK} > 0.6 K_q$

TABLE 016
FRACTURE TOUGHNESS RESULTS FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | KIC (KSI IN ^{0.5}) | Kq (KSI IN ^{0.5}) | COMMENT |
|----------------------------------|--------------------|---------------------------------|--------------------------------|-------------------|
| MCAIR, ST. LOUIS | S-T | 19.9 | 20.3 | (1), (2) VALID |
| MARTIN MARIETTA, LOUISIANA | S-T | | 15.8 14.3 | (1) (1) |
| | AVERAGE | 19.9 | 16.8 | |
| | STANDARD DEVIATION | 0.0 | 3.1 | |

(1): INVALID DUE TO SURFACE TRACE/AVERAGE CRACK ERROR VALUE > VALID REQ
(2): AVERAGE CRACK/W VALUE LESS THAN VALID REQUIREMENT

TABLE 017
FRACTURE TOUGHNESS RESULTS FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | K _{IC} (KSI IN ^{-0.5}) | K _q (KSI IN ^{-0.5}) | COMMENT |
|-----------|--------------------|--|---|---------|
| MARTIN | S-L | | 19.3 | (1) |
| MARIETTA, | | 16.7 | | |
| LOUISIANA | | 15.0 | | |
| | AVERAGE | 15.9 | 19.3 | |
| | STANDARD DEVIATION | 1.2 | 0.0 | |

(1): INVALID DUE TO $a/W=0.552 > 0.55$

TABLE 018
 FATIGUE RESULTS WITH $K_t=1.0$ AND $R=-1.0$ FOR
 KAISER 7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | LIMIT STRESS (KSI) | CYCLES TO FAILURE |
|---------------------|-------------|--------------------------|----------------------|
| MCAIR, ST. LOUIS | LONG | 60.0 | 2,270 |
| | | 55.0 | 5,140 |
| | | 50.0 | 10,750 |
| | | 45.0 | 18,150 |
| | | 40.0 | 86,100 |
| | | 35.0 | 206,670 |
| | | 30.0 | 2,560,000 * |
| | | 25.0 | 1,000,000 * |

(*): INDICATES A RUN OUT TEST

TABLE 019
FATIGUE RESULTS WITH $K_t=1.0$ AND $R=0.1$ FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | LIMIT STRESS (KSI) | CYCLES TO FAILURE |
|---------|-------------|--------------------------|----------------------|
| <hr/> | | | |
| LTV | LONG | 50.0 | 11,600 |
| | | 46.1 | 15,100 |
| | | 44.9 | 17,400 |
| | | 44.0 | 12,100 |
| | | 43.0 | 28,200 |
| | | 42.9 | 18,800 |
| | | 41.7 | 28,000 |
| | | 40.9 | 28,300 |
| | | 40.1 | 10,700 |
| | | 39.7 | 7,400 |
| | | 36.9 | 24,700 |
| | | 36.0 | 285,600 |
| | | 35.2 | 18,000 |
| | | 34.4 | 318,700 |
| | | 33.2 | 3,000,000 * |

(*): INDICATES A RUN-OUT TEST

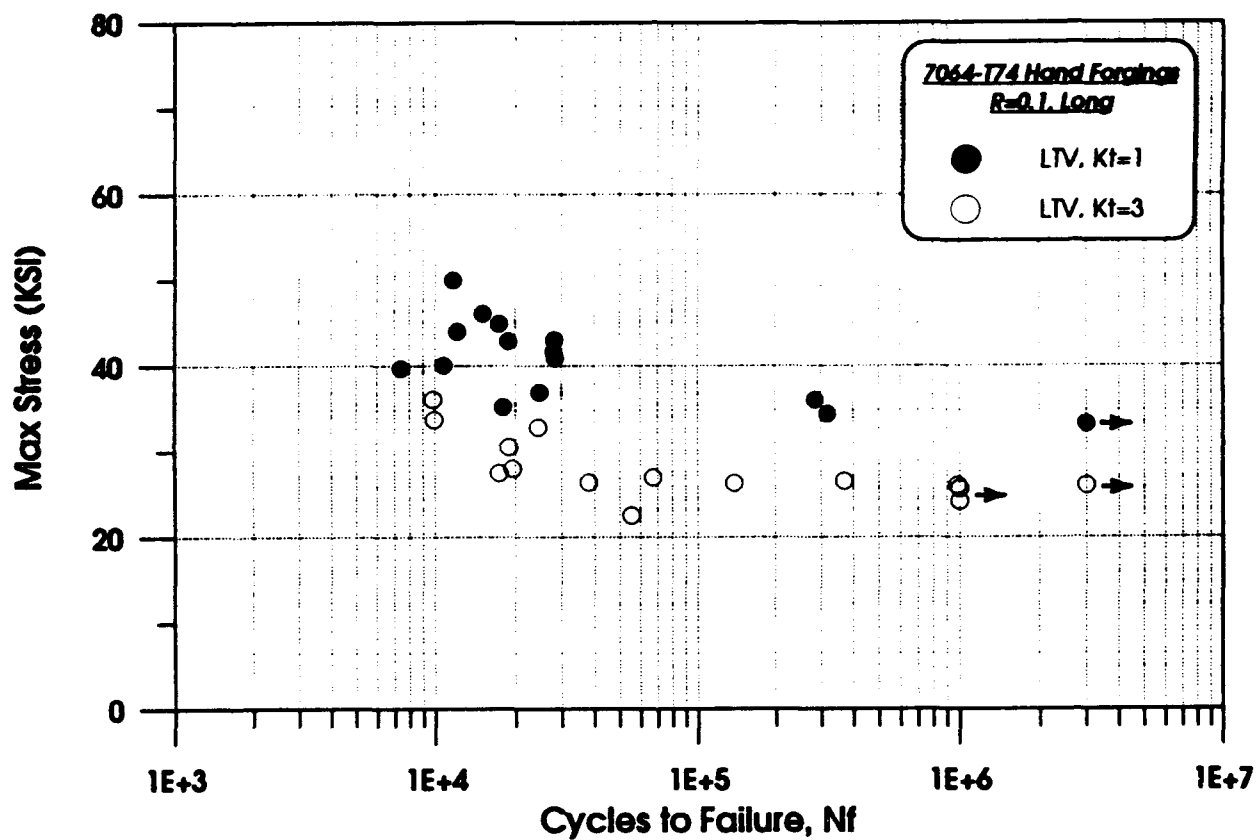


FIGURE O1. FATIGUE DATA for 7064-T74 Hand Forgings (Longitudinal Orientation R=0.1, $K_t=1$ and $K_t=3$). LTV.

TABLE 020

FATIGUE RESULTS WITH $K_t=3.0$ AND $R=0.1$ FOR
KAISER 7064-T74 HAND FORGINGS

| COMPANY | ORIENTATION | LIMIT STRESS (KSI) | CYCLES TO FAILURE |
|---------|-------------|--------------------------|----------------------|
| LTV | LONG | 36.1 | 9,800 |
| | | 33.7 | 9,900 |
| | | 32.8 | 24,500 |
| | | 30.5 | 18,900 |
| | | 28.0 | 19,600 |
| | | 27.5 | 17,400 |
| | | 27.0 | 67,100 |
| | | 26.5 | 368,300 |
| | | 26.4 | 38,100 |
| | | 26.3 | 138,700 |
| | | 26.0 | 983,800 |
| | | 26.0 | 3,000,000 * |
| | | 25.6 | 1,000,000 * |
| | | 24.1 | 1,000,000 * |
| | | 22.5 | 55,500 |

(*): INDICATES A RUN-OUT TEST

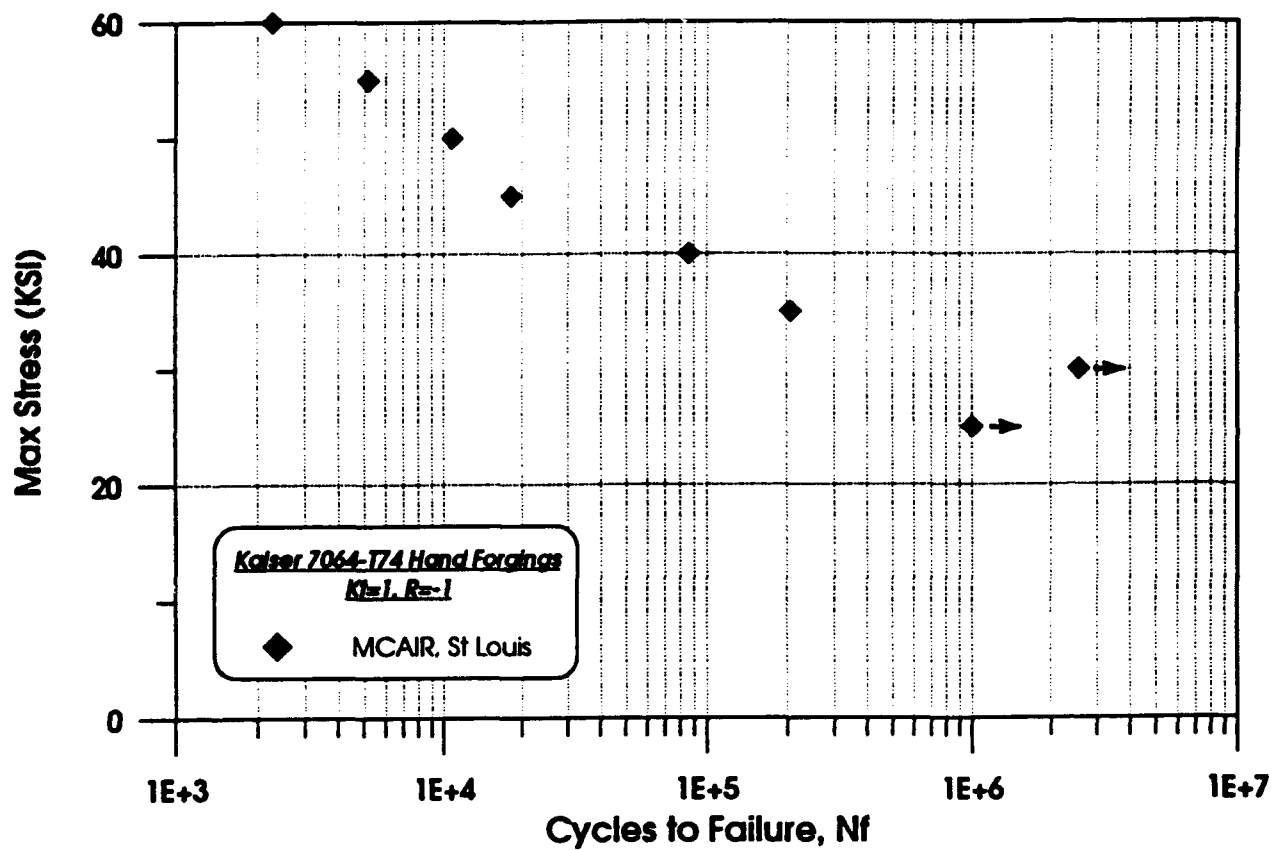
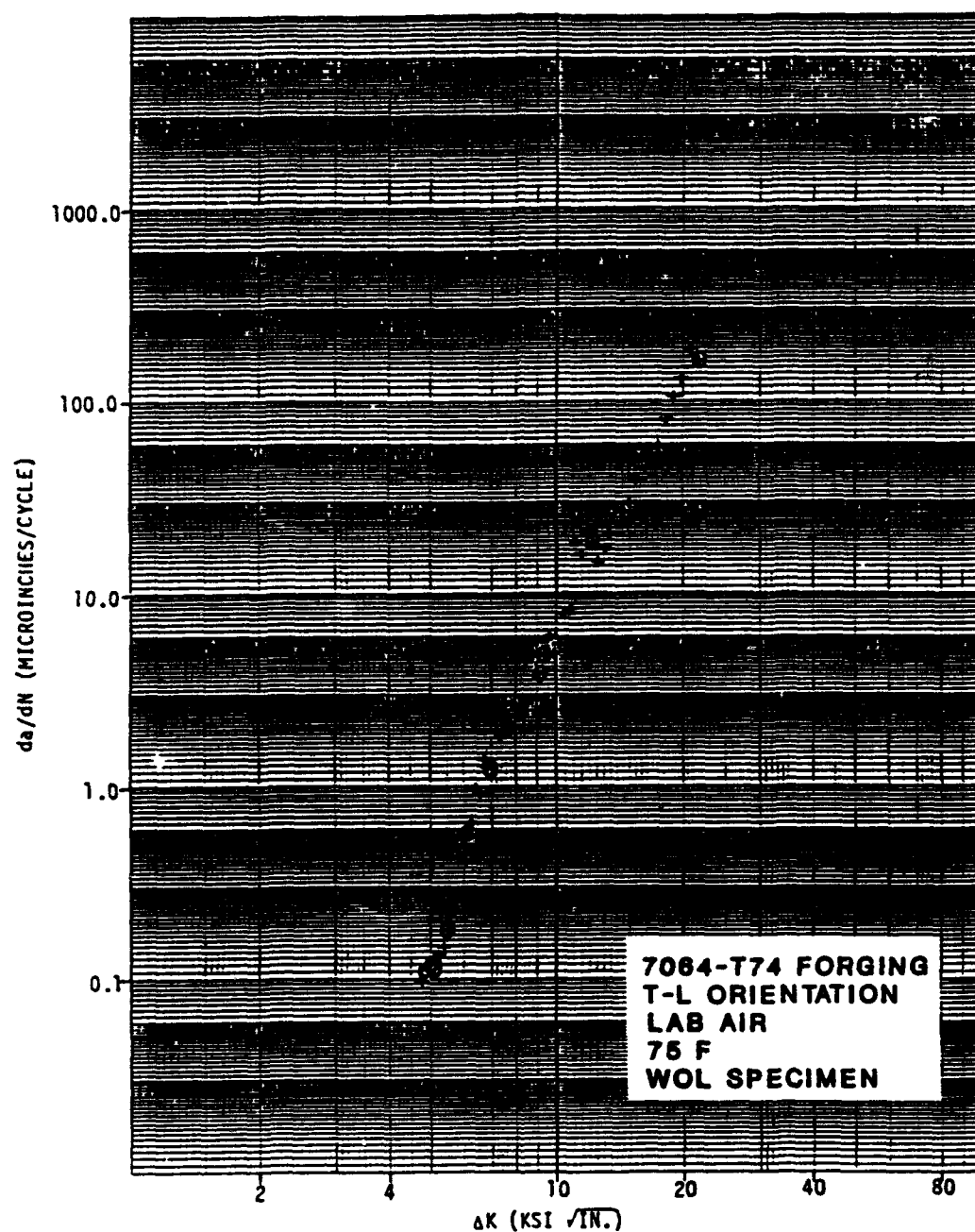


FIGURE O2. FATIGUE DATA FOR 7064-T74 HAND FORGINGS (Longitudinal Orientation, $R=-1.0$, and $K_t=1$). McDonnell Aircraft Company.



● DENOTES THAT DATA POINT IS INVALID PER ASTM E647-83, PARAGRAPH 8.6.4.

FIGURE O3. FATIGUE CRACK GROWTH RATE DATA for 7064-T74 Forging (T-L Orientation, WOL Type Specimen).
McDonnell Aircraft Company.

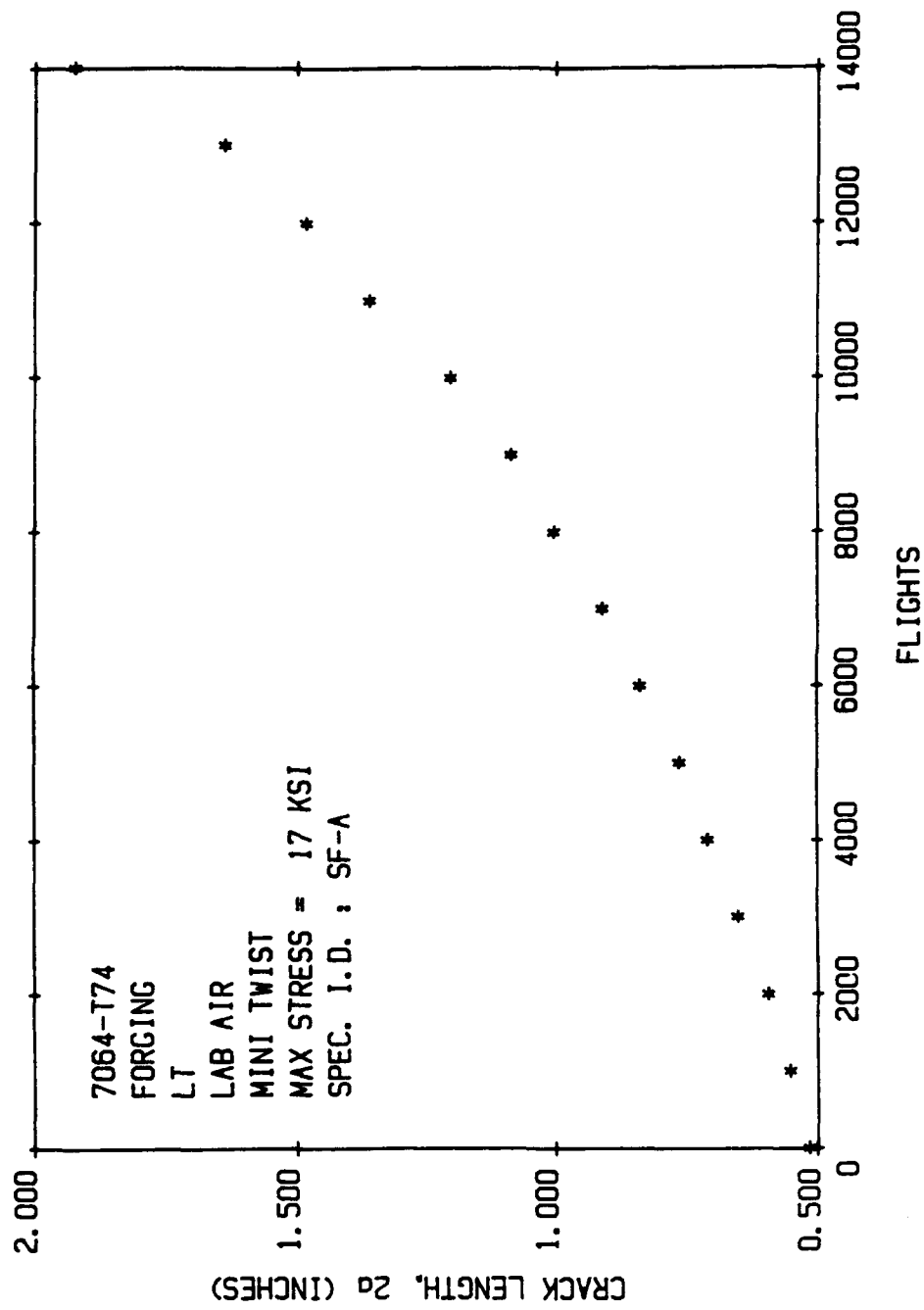


FIGURE O4. Mini-TWIST Spectrum Fatigue Crack Length vs Flights Data for 7064-T74 Forging.
Air Force.

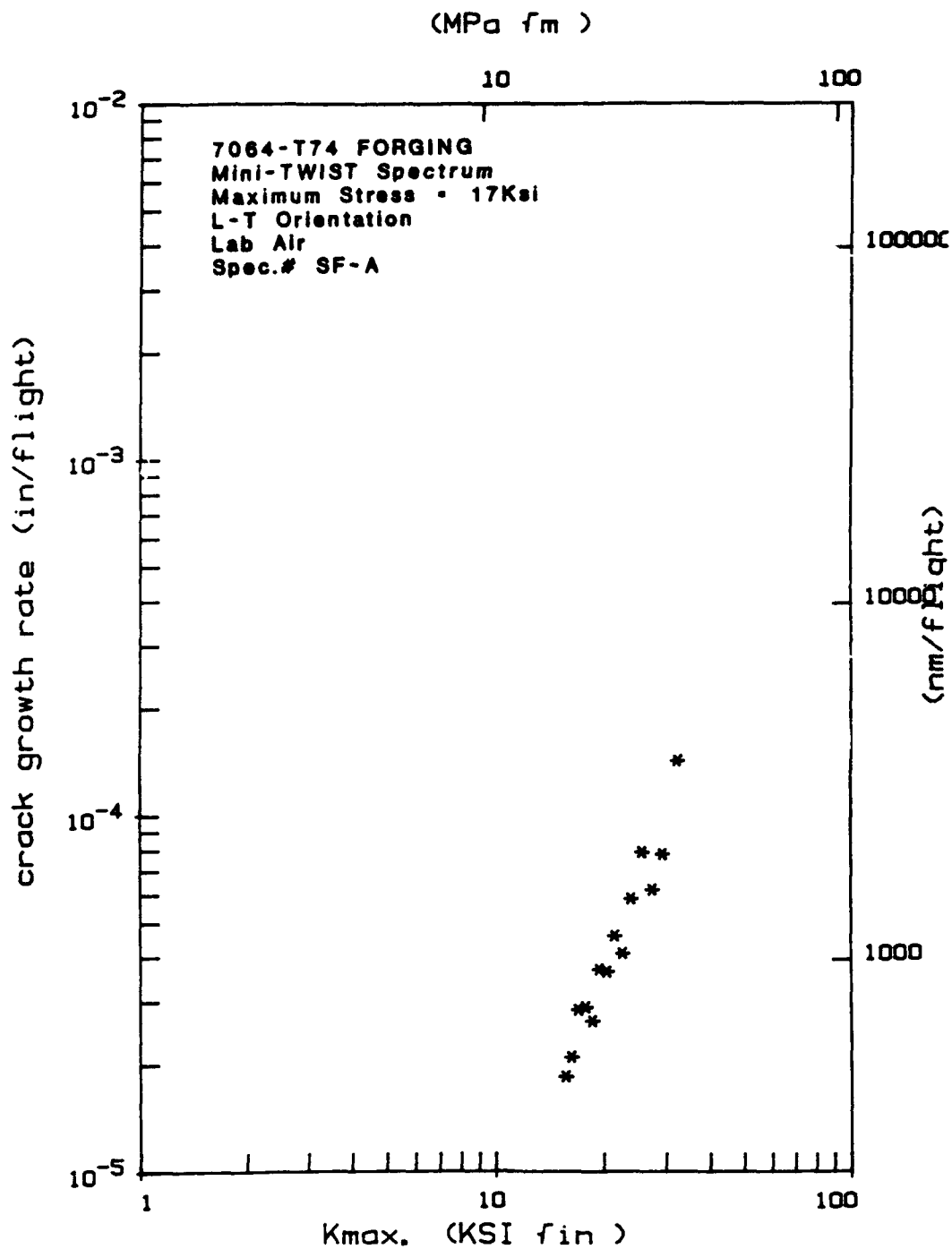


FIGURE O5. Mini-TWIST Spectrum Fatigue Crack Growth Rate Data for 7064-T74 Forging. Air Force.

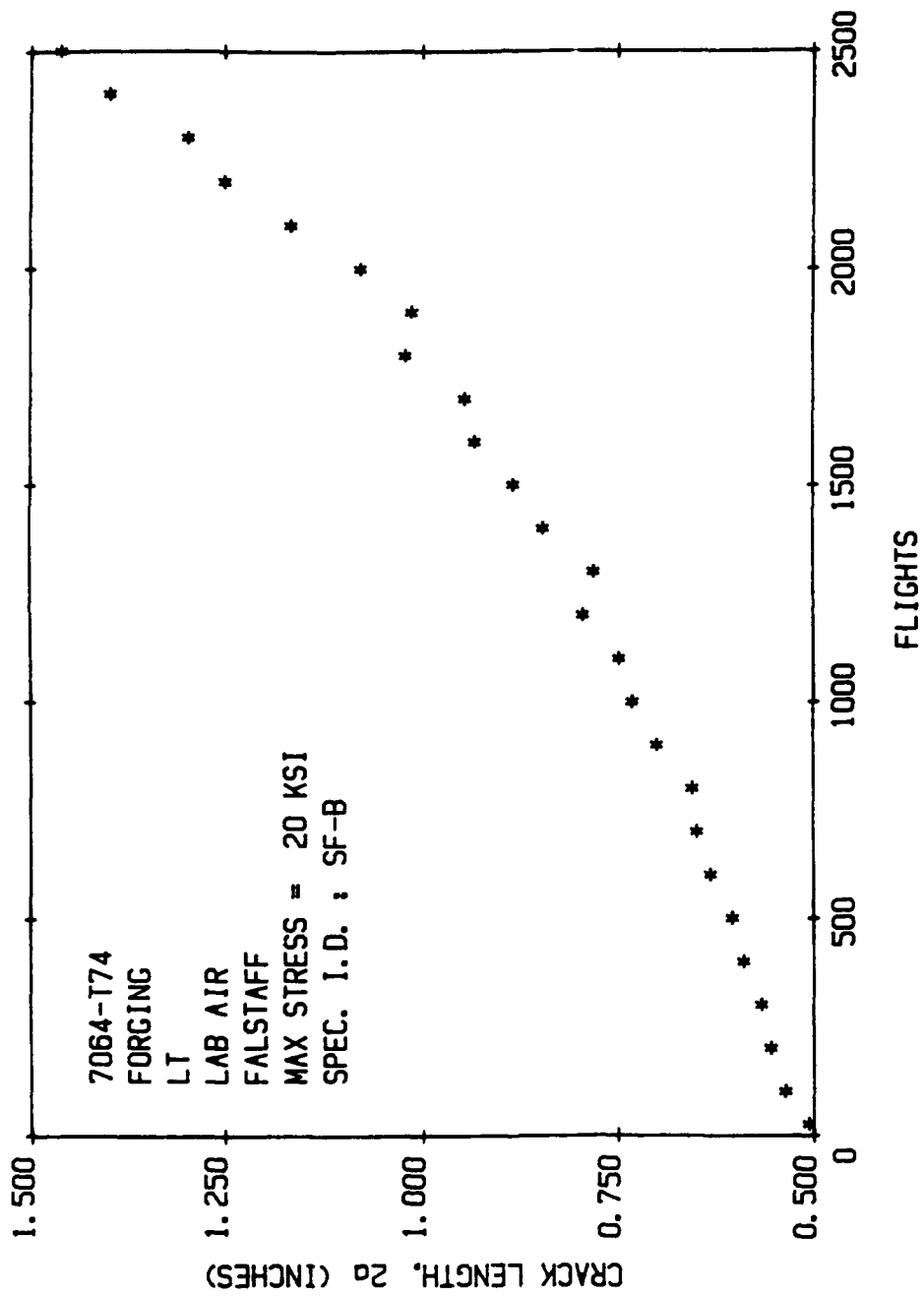
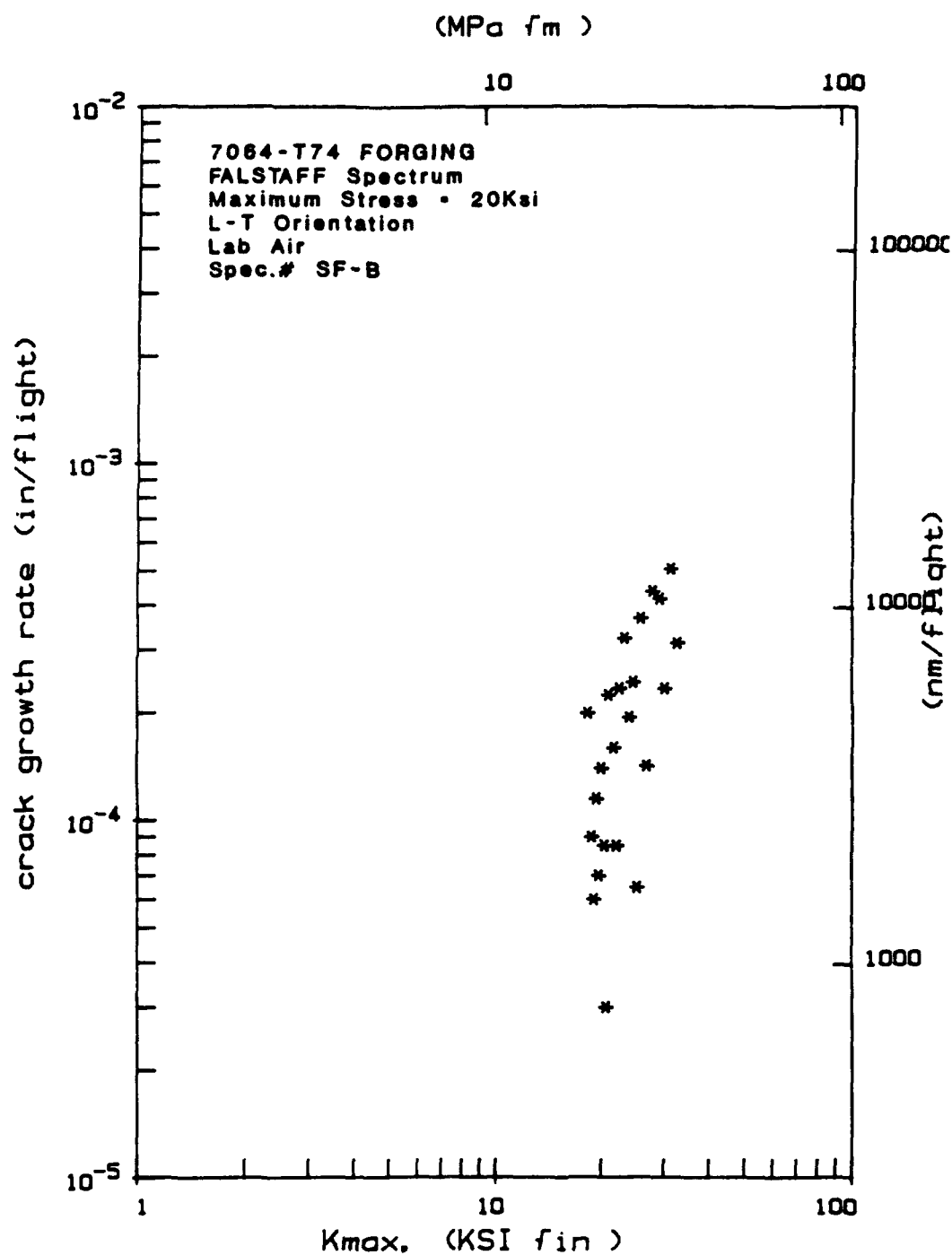


FIGURE O6. FALSTAFF Spectrum Fatigue Crack Length vs Flights Data for 7064-T74 Forging.
Air Force.



APPENDIX P

CW67 SHEET
0.063"X16"X48"

TABLE P1
TENSILE RESULTS FOR ALCOA
CW67 SHEET (0.063" X 16" X 48")

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | E (MSI) |
|------------------------|-----------------------------|------------------|-------------------------------|----------------------------|--------------|-----------|------------|
| MARTIN | RT | LONG | 81.5 | 77.5 | 8.0 | 10.0 | 9.8 |
| MARIETTA, LOUISIANA | | | 81.9 | 78.7 | 7.0 | 10.0 | 9.7 |
| | | | 82.9 | 79.5 | | 6.7 | 9.8 |
| MCDONNELL DOUGLAS | RT | LONG | 80.0 | 77.0 | 6.0 | | 10.0 |
| | | | 80.0 | 77.5 | 8.0 | | 10.4 |
| | | | 81.0 | 78.5 | 6.0 | | 10.0 |
| AVERAGE | | | 81.2 | 78.1 | 7.0 | 8.9 | 10.0 |
| STANDARD DEVIATION | | | 1.1 | 0.9 | 1.0 | 1.9 | 0.3 |

TABLE P2
TENSILE RESULTS FOR ALCOA
CW67 SHEET (0.063" X 16" X 48")

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | E (MSI) |
|------------------------|-----------------------------|------------------|-------------------------------|----------------------------|--------------|-----------|------------|
| MARTIN | RT | L TRANS | 83.5 | 80.8 | | 6.7 | 9.9 |
| MARIETTA, LOUISIANA | | | 83.9 | 82.0 | 3.0 | 3.3 | 10.0 |
| | | | 83.7 | 80.5 | 2.0 | 6.7 | 10.1 |
| MCDONNELL DOUGLAS | RT | L TRANS | 87.5 | 83.0 | 4.0 | | 10.3 |
| | | | 86.5 | 82.0 | 5.0 | | 10.3 |
| | | | 86.5 | 82.0 | 5.0 | | 10.4 |
| AVERAGE | | | 85.3 | 81.7 | 3.8 | 5.6 | 10.2 |
| STANDARD DEVIATION | | | 1.8 | 0.9 | 1.3 | 2.0 | 0.2 |

TABLE P3
COMPRESSION RESULTS FOR ALCOA
CW67 SHEET (0.063" X 16" X 48")

| COMPANY | TEST TEMPERATURE (DEGREES F) | ORIENTATION | COMPRESSIVE YIELD STRENGTH (KSI) | COMPRESSIVE MODULUS (MSI) |
|-----------|------------------------------------|--------------------|--|---------------------------------|
| MCDONNELL | RT | LONG | | 11.2 |
| DOUGLAS | | | | 11.5 |
| | | | 72.0 | 10.3 |
| | | AVERAGE | 72.0 | 11.0 |
| | | STANDARD DEVIATION | 0.0 | 0.6 |

TABLE P4
COMPRESSION RESULTS FOR ALCOA
CW67 SHEET (0.063" X 16" X 48")

| COMPANY | TEST TEMPERATURE (DEGREES F) | ORIENTATION | COMPRESSIVE YIELD STRENGTH (KSI) | COMPRESSIVE MODULUS (MSI) |
|-----------|------------------------------------|--------------------|--|---------------------------------|
| MCDONNELL | RT | L TRANS | | 10.3 |
| DOUGLAS | | | | 10.8 |
| | | | | 11.2 |
| | | AVERAGE | | 10.8 |
| | | STANDARD DEVIATION | | 0.5 |

TABLE P5
SLOTTED SHEAR RESULTS FOR ALCOA
CW67 SHEET (0.063" X 16" X 48")

| COMPANY | ORIENTATION | SHEAR STRENGTH (KSI) |
|-------------------|--------------------|----------------------------|
| <hr/> | | |
| MCDONNELL DOUGLAS | LONG | 31.0 |
| | | 30.0 |
| | | 29.3 |
| | AVERAGE | 30.1 |
| | STANDARD DEVIATION | 0.9 |

TABLE P6
BEARING RESULTS FOR ALCOA
CW67 SHEET (0.063" X 16" X 48")

| COMPANY | ORIENTATION | e/D | BEARING | | BEARING | | |
|--------------------|-------------|-----|---------|------|------------|--|--|
| | | | ULT. | STR. | YIELD STR. | | |
| | | | (KSI) | | (KSI) | | |
| MCDONNELL | LONG | 1.5 | 117.1 | | 101.3 | | |
| DOUGLAS | | | 124.3 | | 107.7 | | |
| | | | 125.5 | | 111.1 | | |
| AVERAGE | | | 122.3 | | 106.7 | | |
| STANDARD DEVIATION | | | 4.5 | | 5.0 | | |

TABLE P7
BEARING RESULTS FOR ALCOA
CW67 SHEET (0.063" X 16" X 48")

| COMPANY | ORIENTATION | e/D | BEARING | | BEARING | | |
|--------------------|-------------|-----|---------|------|------------|--|--|
| | | | ULT. | STR. | YIELD STR. | | |
| | | | (KSI) | | (KSI) | | |
| MCDONNELL | L TRANS | 1.5 | 127.1 | | 112.0 | | |
| DOUGLAS | | | 126.1 | | 108.9 | | |
| | | | 126.6 | | 112.9 | | |
| AVERAGE | | | 126.6 | | 111.3 | | |
| STANDARD DEVIATION | | | 0.5 | | 2.1 | | |

TABLE P8
BEARING RESULTS FOR ALCOA
CW67 SHEET (0.063" X 16" X 48")

| COMPANY | ORIENTATION | e/D | BEARING ULT. STR. (KSI) | BEARING YIELD STR. (KSI) |
|-----------|-------------|--------------------|-------------------------------|--------------------------------|
| MCDONNELL | LONG | 2.0 | 169.4 | 148.8 |
| DOUGLAS | | | 162.0 | 116.3 |
| | | | 163.5 | 139.5 |
| | | AVERAGE | 165.0 | 134.9 |
| | | STANDARD DEVIATION | 3.9 | 16.7 |

TABLE P9
BEARING RESULTS FOR ALCOA
CW67 SHEET (0.063" X 16" X 48")

| COMPANY | ORIENTATION | e/D | BEARING ULT. STR. (KSI) | BEARING YIELD STR. (KSI) |
|-----------|-------------|--------------------|-------------------------------|--------------------------------|
| MCDONNELL | L TRANS | 2.0 | 166.1 | 146.4 |
| DOUGLAS | | | 168.5 | 146.6 |
| | | | 166.2 | 146.4 |
| | | AVERAGE | 166.9 | 146.5 |
| | | STANDARD DEVIATION | 1.4 | 0.1 |

TABLE P10

R-CURVE DATA FOR CW67 0.063 SHEET
(SPECIMEN 32)
McDonnell Aircraft Company

SPECIMEN IDENTIFICATION: 32
MATERIAL DESCRIPTION: CW67 HIGH STRENGTH ALUMINUM SHEET
SPECIMEN TYPE: C(T) (COMPACT SPECIMEN)
SPECIMEN ORIENTATION: L-T
YIELD STRENGTH: 77.7 KSI
SPECIMEN THICKNESS: 0.071 IN
SPECIMEN WIDTH: 3.999 IN

SPECIMEN IS INVALID PER ASTM E561-86, PARA. 7.5

| APPLIED LOAD (lbs) | PHYSICAL CRACK LENGTH (in) | K _r (UNCORRECTED) (psi /in) | EFFECTIVE CRACK LENGTH (in) | K _r (CORRECTED) (psi /in) |
|--------------------------|-------------------------------------|--|--------------------------------------|--|
| 1.025 | 1.519 | 49,842 | 1.591 | 52,248 |
| 1.050 | 1.523 | 51,181 | 1.599 | 53,808 |
| 1.250 | 1.533 | 61,348 | 1.649 | 66,212 |
| 1.325 | 1.592 | 67,582 | 1.739 | 74,594 |
| 1.375 | 1.610 | 70,986 | 1.777 | 79,483 |
| 1.400 | 1.613 | 72,406 | 1.788 | 81,590 |
| 1.425 | 1.638 | 74,930 | 1.831 | 85,575 |
| 1.450 | 1.638 | 76,245 | 1.840 | 87,675 |
| 1.475 | 1.642 | 77,762 | 1.856 | 90,199 |
| 1.500 | 1.660 | 80,039 | 1.894 | 94,283 |
| 1.525 | 1.662 | 81,493 | 1.910 | 96,969 |
| 1.550 | 1.663 | 82,874 | 1.924 | 99,627 |
| 1.600 | 1.667 | 85,818 | 1.963 | 105,834 |
| 1.650 | 1.678 | 89,128 | 2.022 | 114,190 |
| 1.700 | 1.684 | 92,202 | 2.092 | 124,368 |
| 1.725 | 1.706 | 94,972 | *** | *** |
| 1.750 | FAILURE | --- | --- | --- |

*** Indicates that the equation for K_r (Corrected) did not converge to a solution.

TABLE P11

R-CURVE DATA FOR CW67 0.063 SHEET
(SPECIMEN 33)
McDonnell Aircraft Company

SPECIMEN IDENTIFICATION: 33
MATERIAL DESCRIPTION: CW67 HIGH STRENGTH ALUMINUM SHEET
SPECIMEN TYPE: C(T) (COMPACT SPECIMEN)
SPECIMEN ORIENTATION: L-T
YIELD STRENGTH: 77.7 KSI
SPECIMEN THICKNESS: 0.071 IN
SPECIMEN WIDTH: 4.002 IN

| APPLIED LOAD (lbs) | PHYSICAL CRACK LENGTH (in) | Kr (UNCORRECTED) (psi /in) | EFFECTIVE CRACK LENGTH (in) | Kr (CORRECTED) (psi /in) |
|--------------------------|-------------------------------------|----------------------------------|--------------------------------------|--------------------------------|
| 920 | 1.509 | 44,397 | 1.565 | 46,045 |
| 940 | 1.533 | 46,088 | 1.594 | 47,956 |
| 1,000 | 1.545 | 49,395 | 1.615 | 51,743 |
| 1,020 | 1.548 | 50,476 | 1.622 | 52,997 |
| 1,060 | 1.565 | 53,059 | 1.648 | 56,048 |
| 1,100 | 1.569 | 55,188 | 1.659 | 58,602 |
| 1,140 | 1.573 | 57,349 | 1.672 | 61,243 |
| 1,180 | FAILURE | --- | --- | --- |

TABLE P12

R-CURVE DATA FOR CW67 0.063 SHEET
(SPECIMEN 34)
McDonnell Aircraft Company

SPECIMEN IDENTIFICATION: 34
MATERIAL DESCRIPTION: CW67 HIGH STRENGTH ALUMINUM SHEET
SPECIMEN TYPE: C(T) (COMPACT SPECIMEN)
SPECIMEN ORIENTATION: T-L
YIELD STRENGTH: 82.3 KSI
SPECIMEN THICKNESS: 0.071 IN
SPECIMEN WIDTH: 4.002 IN

| APPLIED LOAD (lbs) | PHYSICAL CRACK LENGTH (in) | K _r (UNCORRECTED) (psi /in) | EFFECTIVE CRACK LENGTH (in) | K _r (CORRECTED) (psi /in) |
|--------------------------|-------------------------------------|--|--------------------------------------|--|
| 820 | 1.514 | 39,692 | 1.553 | 40,712 |
| 840 | 1.514 | 40,660 | 1.555 | 41,761 |
| 860 | 1.516 | 41,677 | 1.559 | 42,867 |
| 880 | 1.519 | 42,754 | 1.565 | 44,046 |
| 900 | 1.519 | 43,726 | 1.567 | 45,113 |
| 920 | 1.524 | 44,843 | 1.575 | 46,348 |
| 940 | 1.524 | 45,818 | 1.577 | 47,430 |
| 960 | 1.525 | 46,811 | 1.580 | 48,537 |
| 1,000 | 1.525 | 48,762 | 1.585 | 50,730 |
| 1,020 | 1.526 | 49,786 | 1.590 | 51,892 |
| 1,040 | 1.526 | 50,762 | 1.593 | 53,005 |
| 1,060 | 1.526 | 51,738 | 1.595 | 54,125 |
| 1,080 | 1.529 | 52,786 | 1.601 | 55,336 |
| 1,120 | 1.529 | 54,741 | 1.607 | 57,616 |
| 1,140 | 1.532 | 55,832 | 1.613 | 58,902 |
| 1,160 | 1.534 | 56,893 | 1.619 | 60,164 |
| 1,180 | 1.534 | 57,874 | 1.622 | 61,338 |
| 1,180 | 1.534 | 57,874 | 1.622 | 61,338 |
| 1,200 | 1.534 | 58,854 | 1.626 | 62,520 |
| 1,220 | 1.541 | 60,117 | 1.638 | 64,063 |
| 1,260 | 1.544 | 62,210 | 1.648 | 66,648 |
| 1,280 | 1.546 | 63,272 | 1.654 | 67,979 |
| 1,300 | 1.546 | 64,260 | 1.659 | 69,228 |
| 1,320 | 1.548 | 65,321 | 1.665 | 70,584 |
| 1,340 | 1.562 | 66,926 | 1.686 | 72,682 |
| 1,380 | 1.562 | 68,923 | 1.695 | 75,318 |
| 1,400 | 1.571 | 70,341 | 1.711 | 77,245 |
| 1,420 | 1.575 | 71,552 | 1.722 | 78,913 |
| 1,440 | 1.578 | 72,679 | 1.730 | 80,485 |
| 1,460 | 1.578 | 73,689 | 1.735 | 81,907 |
| 1,468 | FAILURE | --- | --- | --- |

TABLE P13

R-CURVE DATA FOR CW67 0.063 SHEET
(SPECIMEN 35)
McDonnell Aircraft Company

SPECIMEN IDENTIFICATION: 35
MATERIAL DESCRIPTION: CW67 HIGH STRENGTH ALUMINUM SHEET
SPECIMEN TYPE: C(T) (COMPACT SPECIMEN)
SPECIMEN ORIENTATION: T-L
YIELD STRENGTH: 82.3 KSI
SPECIMEN THICKNESS: 0.071 IN
SPECIMEN WIDTH: 4.001 IN

| APPLIED LOAD (lbs) | PHYSICAL CRACK LENGTH (in) | K _r (UNCORRECTED) (psi √in) | EFFECTIVE CRACK LENGTH (in) | K _r (CORRECTED) (psi √in) |
|--------------------------|-------------------------------------|--|--------------------------------------|--|
| 800 | 1.501 | 38,420 | 1.537 | 39,340 |
| 860 | 1.505 | 41,420 | 1.548 | 42,585 |
| 880 | 1.505 | 42,383 | 1.550 | 43,636 |
| 900 | 1.505 | 43,346 | 1.552 | 44,692 |
| 920 | 1.505 | 44,310 | 1.555 | 45,753 |
| 940 | 1.507 | 45,320 | 1.559 | 46,871 |
| 960 | 1.507 | 46,284 | 1.561 | 47,943 |
| 980 | 1.507 | 47,248 | 1.563 | 49,021 |
| 1,000 | 1.509 | 48,260 | 1.568 | 50,158 |
| 1,020 | 1.509 | 49,225 | 1.570 | 51,248 |
| 1,040 | 1.514 | 50,363 | 1.579 | 52,544 |
| 1,060 | 1.517 | 51,449 | 1.585 | 53,788 |
| 1,080 | 1.517 | 52,419 | 1.588 | 54,906 |
| 1,100 | 1.521 | 53,526 | 1.595 | 56,191 |
| 1,120 | 1.521 | 54,499 | 1.598 | 57,328 |
| 1,140 | 1.521 | 55,472 | 1.602 | 58,471 |
| 1,160 | 1.521 | 56,445 | 1.605 | 59,623 |
| 1,180 | 1.523 | 57,482 | 1.610 | 60,860 |
| 1,200 | 1.523 | 58,456 | 1.613 | 62,031 |
| 1,220 | 1.523 | 59,430 | 1.617 | 63,210 |
| 1,240 | 1.523 | 60,405 | 1.620 | 64,398 |
| 1,260 | 1.643 | 66,427 | 1.765 | 72,199 |
| 1,280 | 1.643 | 67,482 | 1.770 | 73,588 |
| 1,300 | 1.643 | 68,536 | 1.775 | 74,994 |
| 1,320 | 1.650 | 69,917 | 1.789 | 76,881 |
| 1,340 | 1.665 | 71,679 | 1.813 | 79,365 |
| 1,360 | 1.665 | 72,749 | 1.818 | 80,873 |
| 1,380 | 1.671 | 74,137 | 1.832 | 82,893 |
| 1,388 | FAILURE | --- | --- | --- |

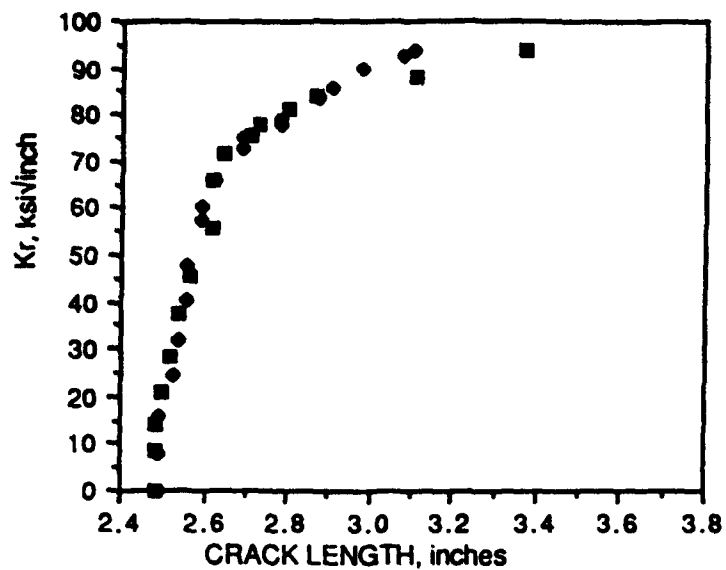


FIGURE P1. R-CURVE DATA for CW67 0.063 Inch Sheet (L-T Orientation).
Martin Marietta.

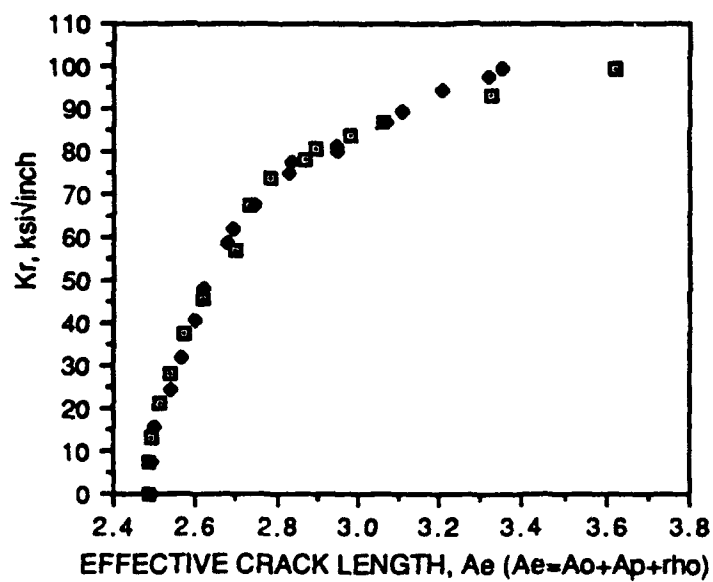


FIGURE P2. R-CURVE EFFECTIVE CRACK LENGTH ADJUSTED for PLASTIC ZONE
(L-T Orientation).
Martin Marietta.

TABLE P14
R-CURVE DATA ASSOCIATED WITH FIGURES P1 AND P2
(SPECIMEN 1)

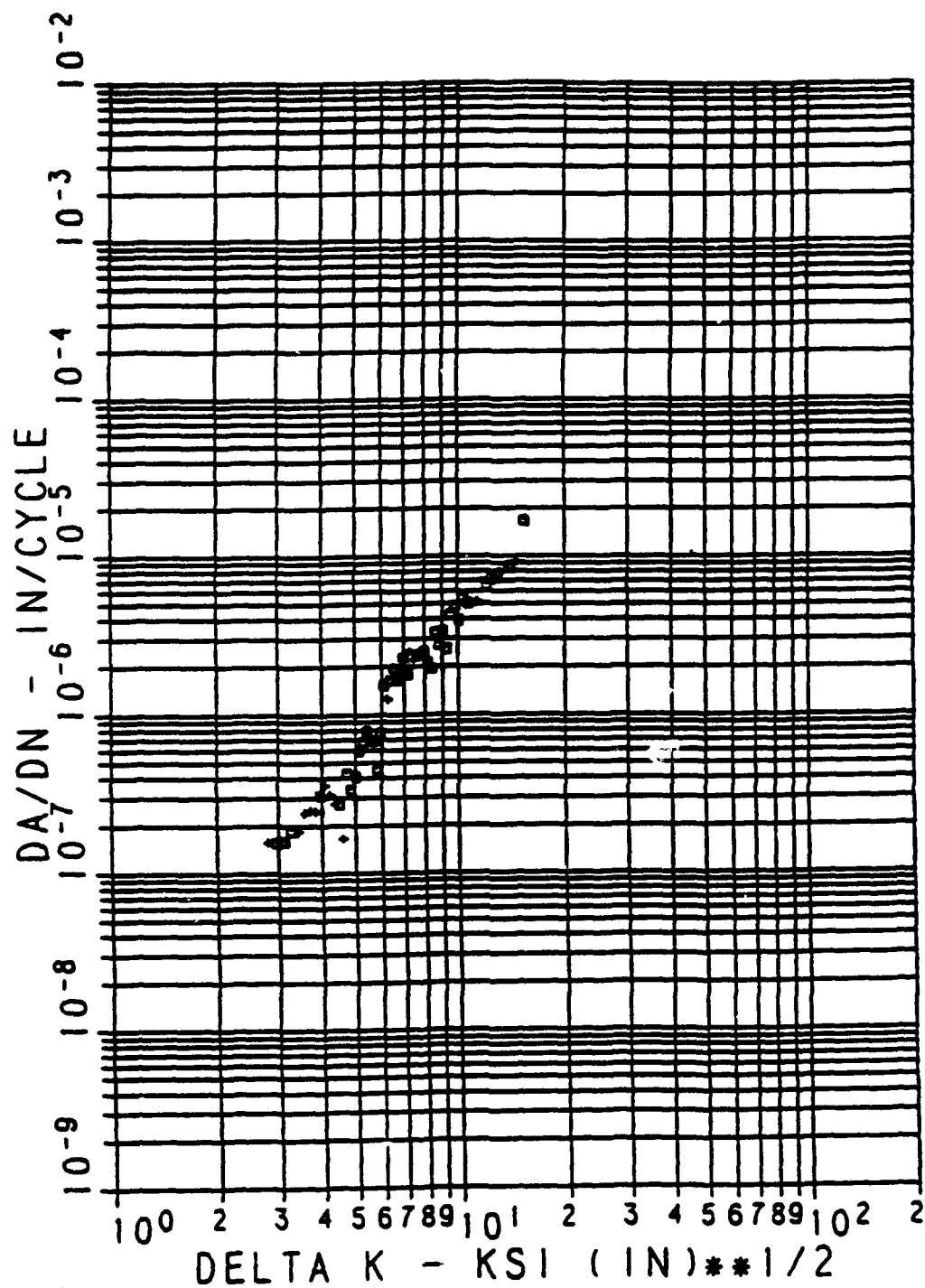
| Load, kips | Half Crack Length (a) inch | Half Crack Length, (a + rho) inch | Corresponding Fracture Toughness, ksi $\sqrt{\text{inch}}$ | |
|------------|-------------------------------|---|---|----------------------------|
| | | | Not Adjusted | Adjusted for Plasticity |
| 0 | 2.485 | 2.485 | 0.0 | 0.0 |
| 2.50 | 2.485 | 2.487 | 8.3 | 7.8 |
| 4.25 | 2.485 | 2.490 | 14.1 | 13.2 |
| 6.40 | 2.500 | 2.512 | 21.3 | 21.4 |
| 8.45 | 2.520 | 2.541 | 28.3 | 28.4 |
| 11.10 | 2.535 | 2.571 | 37.3 | 37.6 |
| 13.35 | 2.565 | 2.619 | 45.2 | 45.8 |
| 16.30 | 2.615 | 2.698 | 55.9 | 56.9 |
| 19.25 | 2.615 | 2.733 | 66.1 | 67.7 |
| 20.75 | 2.645 | 2.785 | 71.8 | 73.8 |
| 21.50 | 2.710 | 2.866 | 75.6 | 77.9 |
| 22.15 | 2.710 | 2.893 | 78.1 | 80.7 |
| 22.60 | 2.800 | 2.982 | 81.2 | 84.0 |
| 23.00 | 2.865 | 3.060 | 83.9 | 87.0 |
| 22.85 | 3.105 | 3.327 | 88.3 | 92.9 |
| 22.90 | 3.365 | 3.620 | 94.0 | 99.5 |

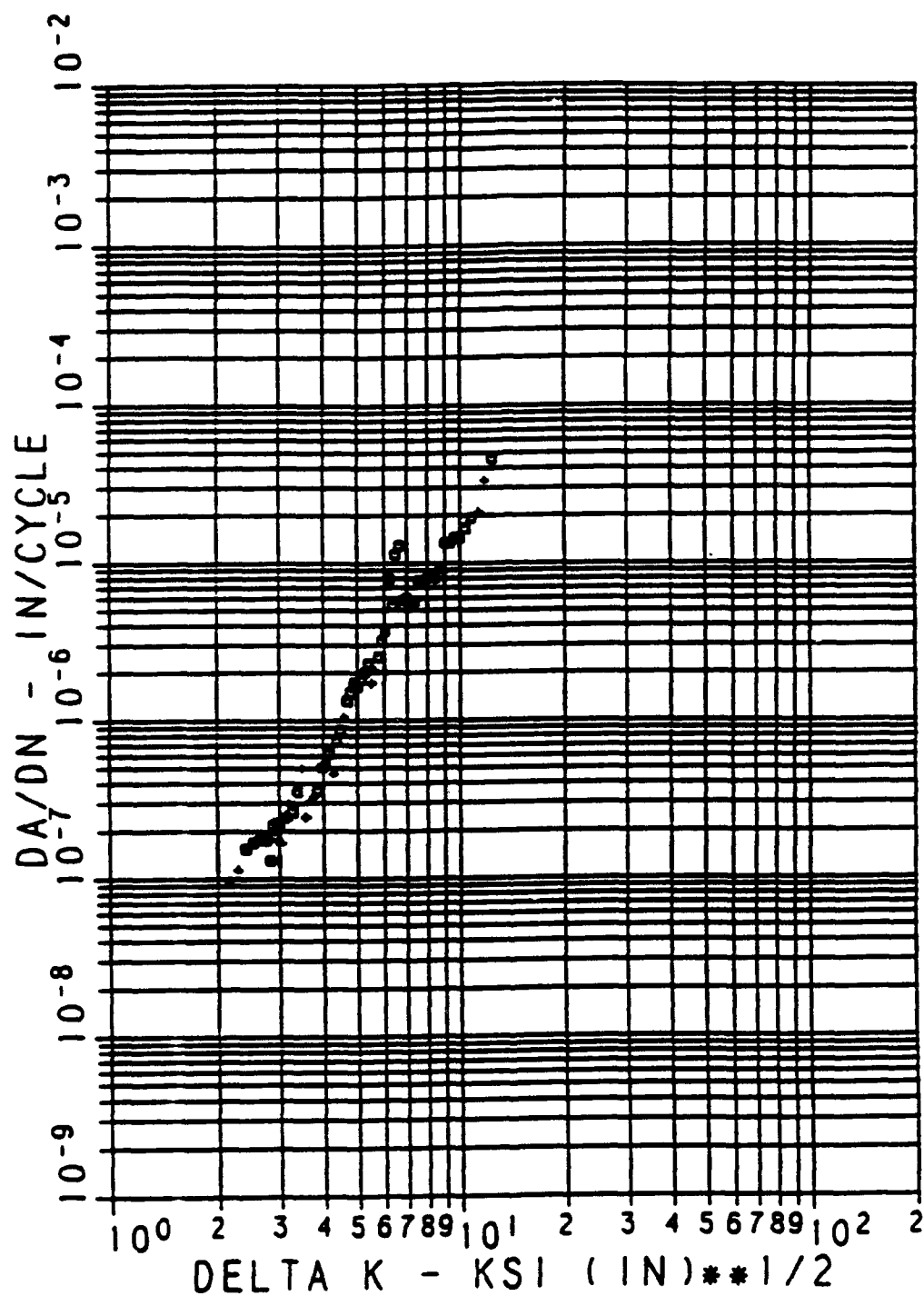
Thickness = .058 inches
Yield Strength = 78.6 ksi
Specimen Width = 15.50 inches

TABLE P15
R-CURVE DATA ASSOCIATED WITH FIGURES P1 and P2
(SPECIMEN 2)

| Load, kips | Half Crack Length (a), inch | Half Crack Length (a + rho), inch | Corresponding Fracture Toughness, ksi $\sqrt{\text{inch}}$ | |
|------------|--------------------------------|---|---|----------------------------|
| | | | Not Adjusted | Adjusted for Plasticity |
| 0 | 2.490 | 2.490 | 0.0 | 0.0 |
| 2.8 | 2.490 | 2.492 | 8.2 | 7.7 |
| 5.4 | 2.490 | 2.496 | 15.8 | 15.8 |
| 8.2 | 2.525 | 2.540 | 24.2 | 24.3 |
| 10.8 | 2.535 | 2.562 | 31.9 | 32.1 |
| 13.5 | 2.555 | 2.597 | 40.1 | 40.5 |
| 16.0 | 2.555 | 2.615 | 47.5 | 48.1 |
| 19.3 | 2.590 | 2.680 | 57.4 | 58.9 |
| 20.2 | 2.590 | 2.688 | 60.5 | 61.8 |
| 21.8 | 2.625 | 2.742 | 65.9 | 67.5 |
| 23.7 | 2.685 | 2.829 | 72.7 | 74.9 |
| 24.4 | 2.685 | 2.839 | 74.9 | 77.2 |
| 24.7 | 2.780 | 2.945 | 77.6 | 80.1 |
| 25.1 | 2.780 | 2.951 | 78.9 | 81.5 |
| 26.1 | 2.870 | 3.065 | 83.8 | 86.9 |
| 26.5 | 2.905 | 3.109 | 85.8 | 89.1 |
| 27.2 | 2.975 | 3.205 | 89.6 | 94.4 |
| 27.4 | 3.075 | 3.321 | 92.4 | 97.7 |
| 27.6 | 3.100 | 3.353 | 93.6 | 99.1 |

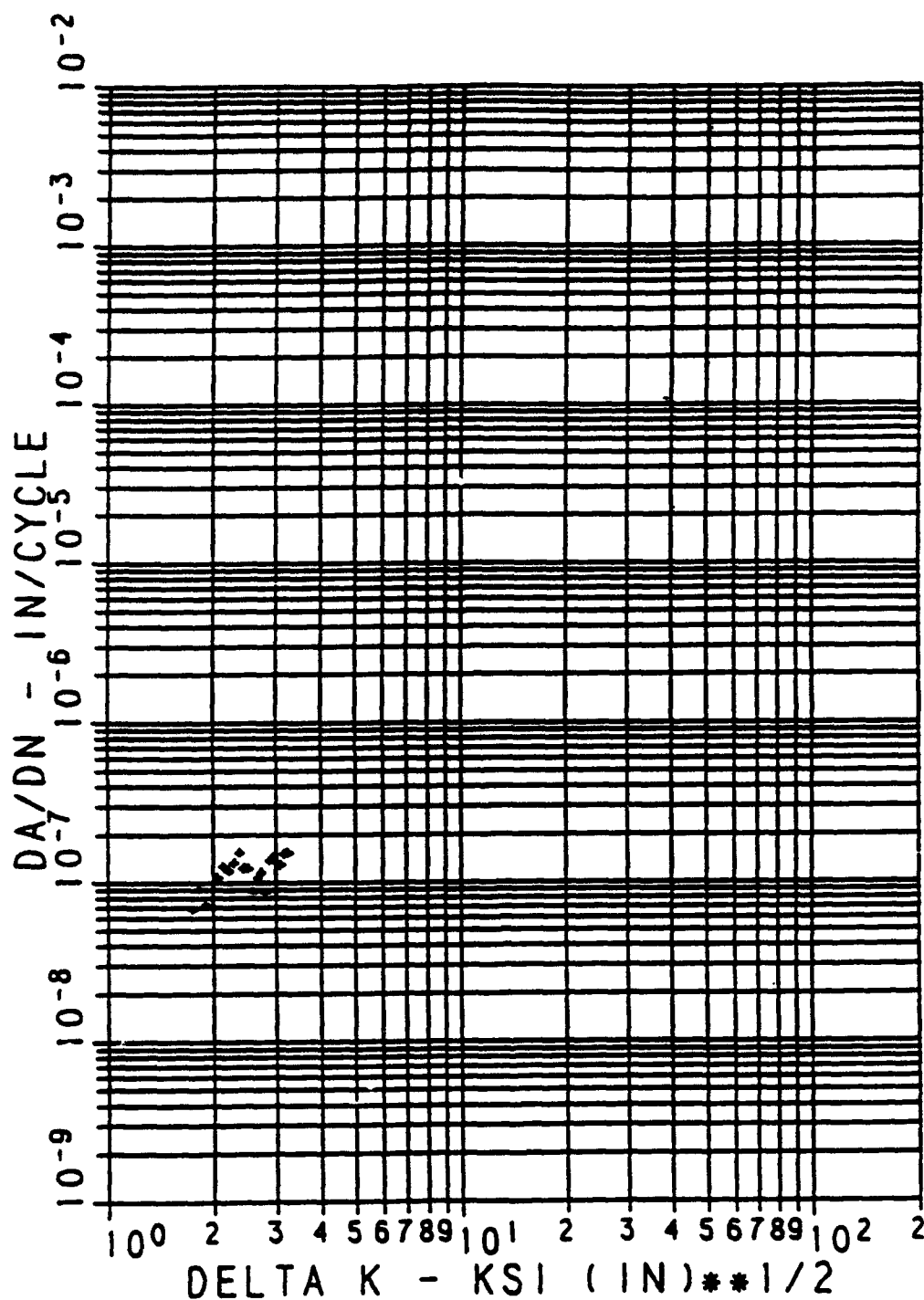
Thickness = 0.066 inches
Yield Strength = 78.6 ksi
Specimen Width = 15.50 inches





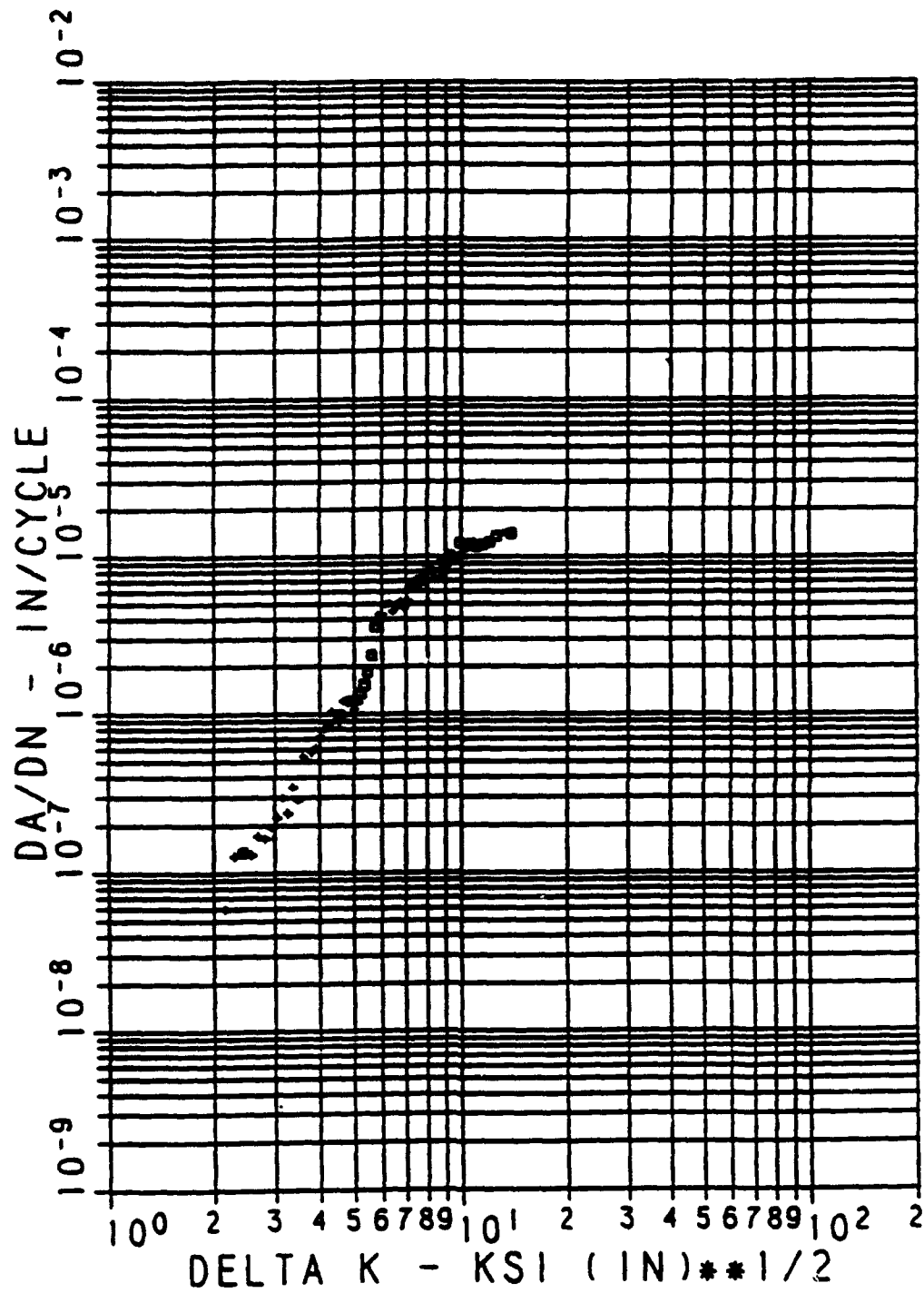
■ #7
 • #7 - INVALID DATA PER ASTM E647-88

FIGURE P4. FATIGUE CRACK GROWTH RATE DATA for CW67 0.063 Sheet
 (L-T Orientation, R=0.33, Lab Air, Room Temperature and Specimen #7).
 McDonnell Aircraft Company.



■ #4
 • #4 - INVALID DATA PER ASTM E647-88

FIGURE P5. FATIGUE CRACK GROWTH RATE DATA for CW67 0.063 Sheet
 (T-L Orientation, R=0.1, Lab Air, Room Temperature and Specimen #4).
 McDonnell Aircraft Company.



■ #5
 • #5 - INVALID DATA PER ASTM E647-88

FIGURE P6. FATIGUE CRACK GROWTH RATE DATA for CW67 0.063 " Sheet
 (T-L Orientation, R=0.33, Lab Air, Room Temperature and Specimen #5).
 McDonnell Aircraft Company.

APPENDIX Q

CW67 PLATE
0.4"X16"X48"

TABLE Q1
TENSILE RESULTS FOR ALCOA
CW67 PLATE (0.4" X 16" X 48")

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | E (MSI) |
|----------------------------------|-----------------------------|--------------------|-------------------------------|----------------------------|--------------|-----------|------------|
| MARTIN MARIETTA, LOUISIANA | RT | LONG | 81.8 | 79.1 | 11.0 | 18.1 | 9.8 |
| | | | 81.1 | 77.2 | 13.0 | 23.1 | 9.8 |
| | | | 82.0 | 78.4 | 12.5 | 24.7 | 9.9 |
| | | AVERAGE | 81.6 | 78.2 | 12.2 | 22.0 | 9.8 |
| | | STANDARD DEVIATION | 0.5 | 1.0 | 1.0 | 3.4 | 0.1 |

TABLE Q2
TENSILE RESULTS FOR ALCOA
CW67 PLATE (0.4" X 16" X 48")

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | E (MSI) |
|----------------------------------|-----------------------------|--------------------|-------------------------------|----------------------------|--------------|-----------|------------|
| MARTIN MARIETTA, LOUISIANA | RT | L TRANS | 88.8 | 84.6 | 6.0 | 5.6 | 9.9 |
| | | | 87.8 | 83.8 | 6.0 | 6.1 | 10.3 |
| | | | 86.9 | 83.6 | 6.5 | 6.6 | 10.1 |
| | | AVERAGE | 87.8 | 84.0 | 6.2 | 6.1 | 10.1 |
| | | STANDARD DEVIATION | 1.0 | 0.5 | 0.3 | 0.5 | 0.2 |

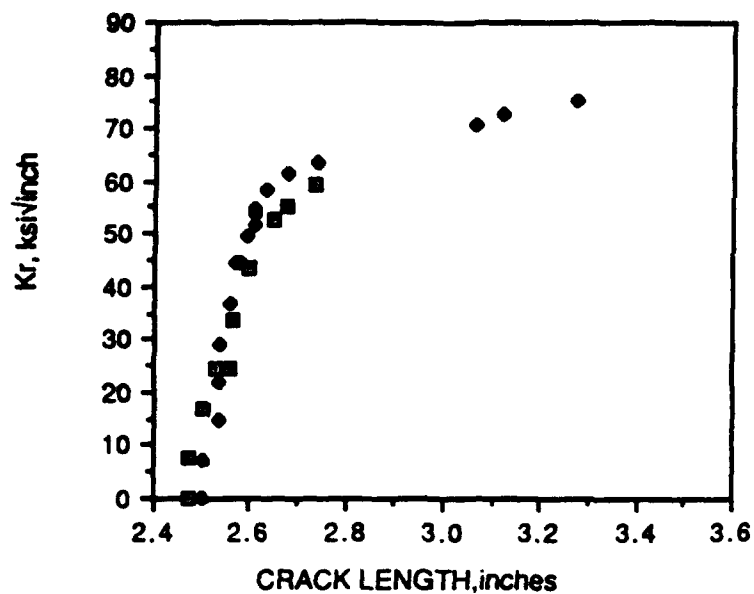


FIGURE Q1. R-CURVE DATA for CW67 0.4 INCH PLATE (L-T ORIENTATION).
Martin Marietta.

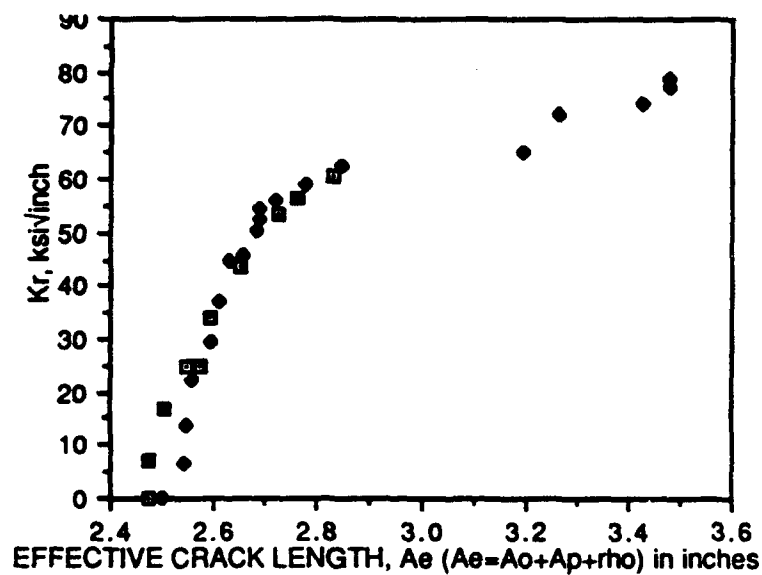


FIGURE Q2. R-CURVE EFFECTIVE CRACK LENGTH ADJUSTED for Plastic Zone Data for CW67 0.4 Inch Plate (L-T Orientation).
Martin Marietta.

TABLE Q3
R-CURVE DATA ASSOCIATED WITH FIGURES Q1 AND Q2
(SPECIMEN 1)

| Load, kips | Half Crack Length (a), inch | Half Crack Length (a + rho), inch | Corresponding Fracture Toughness, ksi $\sqrt{\text{inch}}$ | |
|------------|-----------------------------|-----------------------------------|--|-------------------------|
| | | | Not Adjusted | Adjusted for Plasticity |
| 0 | 2.475 | 2.475 | 0.0 | 0.0 |
| 16.1 | 2.475 | 2.476 | 7.8 | 7.3 |
| 34.3 | 2.500 | 2.507 | 16.8 | 16.8 |
| 50.2 | 2.503 | 2.546 | 24.7 | 24.8 |
| 50.2 | 2.506 | 2.576 | 24.7 | 25.0 |
| 68.5 | 2.507 | 2.596 | 34.0 | 34.3 |
| 86.6 | 2.600 | 2.650 | 43.4 | 43.9 |
| 103.4 | 2.650 | 2.724 | 52.5 | 53.3 |
| 108.0 | 2.680 | 2.762 | 55.2 | 56.2 |
| 114.8 | 2.735 | 2.831 | 59.2 | 60.7 |

Thickness = 0.396 inches
Yield Strength = 78.2 ksi
Specimen Width = 15.49 inches

TABLE Q4
R-CURVE DATA ASSOCIATED WITH FIGURES Q1 and Q2
(SPECIMEN 2)

| Load, kips | Half Crack Length (a), inch | Half Crack Length (a + rno), inch | Corresponding Fracture Toughness, ksi v inch | |
|------------|--------------------------------|---|---|----------------------------|
| | | | Not Adjusted | Adjusted for Plasticity |
| 0 | 2.500 | 2.501 | 0.0 | 0.0 |
| 15.0 | 2.500 | 2.540 | 7.3 | 6.8 |
| 29.9 | 2.535 | 2.548 | 14.6 | 13.6 |
| 45.5 | 2.535 | 2.558 | 22.2 | 22.3 |
| 60.1 | 2.535 | 2.596 | 29.3 | 29.5 |
| 75.2 | 2.560 | 2.609 | 36.9 | 37.2 |
| 90.3 | 2.570 | 2.634 | 44.4 | 44.8 |
| 91.5 | 2.580 | 2.656 | 44.4 | 45.7 |
| 100.6 | 2.590 | 2.682 | 49.8 | 50.5 |
| 104.3 | 2.610 | 2.688 | 51.8 | 52.6 |
| 108.1 | 2.610 | 2.691 | 53.7 | 54.6 |
| 110.5 | 2.610 | 2.721 | 54.9 | 55.9 |
| 116.3 | 2.630 | 2.777 | 58.1 | 59.2 |
| 121.1 | 2.675 | 2.850 | 61.2 | 62.4 |
| 123.8 | 2.740 | 3.196 | 63.6 | 65.0 |
| 127.1 | 3.060 | 3.264 | 70.5 | 72.2 |
| 129.0 | 3.120 | 3.425 | 72.5 | 74.4 |
| 129.0 | 3.270 | 3.481 | 75.1 | 77.1 |
| 129.8 | 3.320 | 3.481 | 76.5 | 78.6 |

Thickness = 0.396 inches
Yield Strength = 78.2 ksi
Specimen Width = 15.50 inches

APPENDIX R
CW67 EXTRUISION
1.5"X4.5"X36"

TABLE R1
TENSILE RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | E (MSI) |
|-----------|-----------------------------|--------------------|-------------------------------|----------------------------|--------------|-----------|------------|
| LTV | RT | LONG | 86.4 | 81.3 | 10.5 | | 10.2 |
| | | | 85.9 | 81.3 | 11.4 | | 10.0 |
| | | | 85.9 | 81.3 | 12.3 | | 9.9 |
| | | | 85.5 | 78.6 | 12.3 | | 9.4 |
| | | | 86.1 | 80.4 | 11.7 | | 9.5 |
| AIR FORCE | RT | LONG | 89.1 | 84.9 | 10.0 | 28.0 | |
| | | | 86.2 | 81.5 | 9.5 | 27.0 | |
| | | | 85.5 | 80.6 | 15.2 | 28.7 | |
| MCAIR | RT | LONG | 86.0 | 81.5 | 10.0 | 35.0 | 14.3 |
| | | | 83.0 | 79.0 | 14.0 | 38.0 | 13.4 |
| | | | 82.5 | 77.5 | 12.0 | 36.0 | 13.7 |
| | | AVERAGE | 85.6 | 80.7 | 11.7 | 32.1 | 11.3 |
| | | STANDARD DEVIATION | 1.7 | 1.9 | 1.7 | 4.7 | 2.1 |

TABLE R2
TENSILE RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | E (MSI) | | | |
|-----------|-----------------------------|------------------|-------------------------------|----------------------------|--------------|-----------|------------|------|------|------|
| LTV | RT | L TRANS | 80.9 | 75.0 | 10.0 | | 10.0 | | | |
| | | | 81.0 | 75.0 | 12.0 | | 11.1 | | | |
| | | | 81.6 | 71.0 | 11.2 | | 12.9 | | | |
| | | | 80.9 | 72.3 | 9.1 | | 11.0 | | | |
| | | | 80.9 | | 10.9 | | 12.9 | | | |
| AIR FORCE | RT | L TRANS | 82.5 | 77.4 | 10.0 | 26.0 | | | | |
| | | | 83.1 | 78.2 | 10.7 | 35.0 | | | | |
| | | | 82.3 | 76.7 | 8.4 | 20.4 | | | | |
| MCAIR | RT | L TRANS | 81.5 | 76.5 | 12.0 | 32.0 | 14.0 | | | |
| | | | 81.0 | 72.0 | 10.0 | 27.0 | 14.0 | | | |
| | | | 81.5 | 76.0 | 15.0 | 35.0 | 13.6 | | | |
| | | | AVERAGE | | | 81.6 | 75.0 | 10.8 | 29.2 | 12.4 |
| | | | STANDARD DEVIATION | | | 0.8 | 2.5 | 1.8 | 5.8 | 1.5 |

TABLE R3
COMPRESSION RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | TEST TEMPERATURE (DEGREES F) | ORIENTATION | COMPRESSIVE YIELD STRENGTH (KSI) | COMPRESSIVE MODULUS (MSI) |
|---------|------------------------------------|--------------------|--|---------------------------------|
| MCAIR | RT | LONG | 78.5 | 10.8 |
| | | | 80.0 | 10.9 |
| | | | 79.5 | 11.0 |
| | | AVERAGE | 79.3 | 10.9 |
| | | STANDARD DEVIATION | 0.8 | 0.1 |

TABLE R4
COMPRESSION RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | TEST TEMPERATURE (DEGREES F) | ORIENTATION | COMPRESSIVE YIELD STRENGTH (KSI) | COMPRESSIVE MODULUS (MSI) |
|---------|------------------------------------|--------------------|--|---------------------------------|
| MCAIR | RT | L TRANS | 80.0 | 11.2 |
| | | | 74.0 | 10.8 |
| | | | 79.0 | 10.8 |
| | | AVERAGE | 77.7 | 10.9 |
| | | STANDARD DEVIATION | 3.2 | 0.2 |

TABLE R5
IOSIPESCU SHEAR RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | ORIENTATION | SHEAR STRENGTH (KSI) |
|---------|--------------------|----------------------------|
| LTV | LONG | 49.8 |
| | | 50.0 |
| | | 49.9 |
| | | 48.1 |
| | | 48.7 |
| | | 50.7 |
| | AVERAGE | 49.5 |
| | STANDARD DEVIATION | 1.0 |

TABLE R6
IOSIPESCU SHEAR RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | ORIENTATION | SHEAR STRENGTH (KSI) |
|---------|--------------------|----------------------------|
| LTV | L TRANS | 51.5 |
| | | 51.2 |
| | | 51.5 |
| | | 48.9 |
| | | 48.6 |
| | | 51.0 |
| | AVERAGE | 50.5 |
| | STANDARD DEVIATION | 1.3 |

TABLE R7
 AMSLER DOUBLE SHEAR RESULTS FOR
 ALCOA CW67 EXTRUSION

| COMPANY | ORIENTATION | SHEAR STRENGTH (KSI) |
|---------|--------------------|----------------------------|
| MCAIR | L - S | 52.1 |
| | | 48.3 |
| | | 48.5 |
| | AVERAGE | 49.6 |
| | STANDARD DEVIATION | 2.1 |

TABLE R8
BEARING RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | ORIENTATION | e/D | BEARING | | BEARING | |
|---------|-------------|--------------------|---------|---------------|---------|---------------|
| | | | ULT. | STR. (KSI) | YIELD | STR. (KSI) |
| LTV | LONG | 1.5 | | 124.0 | | 103.0 |
| | | | | 123.0 | | 104.0 |
| | | | | 126.0 | | 106.0 |
| MCAIR | LONG | 1.5 | | 126.9 | | 112.1 |
| | | | | 122.9 | | 107.2 |
| | | AVERAGE | | 124.6 | | 106.5 |
| | | STANDARD DEVIATION | | 1.8 | | 3.6 |

TABLE R9
BEARING RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | ORIENTATION | e/D | BEARING | | BEARING | |
|---------|-------------|--------------------|---------|---------------|---------|---------------|
| | | | ULT. | STR. (KSI) | YIELD | STR. (KSI) |
| LTV | L TRANS | 1.5 | | 122.0 | | 109.0 |
| | | | | 123.0 | | 108.0 |
| | | | | 129.0 | | 112.0 |
| MCAIR | L TRANS | 1.5 | | 123.7 | | 107.4 |
| | | | | 121.7 | | 105.7 |
| | | AVERAGE | | 123.9 | | 108.4 |
| | | STANDARD DEVIATION | | 3.0 | | 2.3 |

TABLE R10
BEARING RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | ORIENTATION | e/D | BEARING | | BEARING |
|--------------------|-------------|-----|---------|-------|------------|
| | | | ULT. | STR. | YIELD STR. |
| | | | (KSI) | | (KSI) |
| LTV | LONG | 2.0 | | 158.0 | 118.0 |
| | | | | 155.0 | 126.0 |
| | | | | 156.0 | 121.0 |
| MCAIR | LONG | 2.0 | | 174.2 | 144.4 |
| | | | | 171.0 | 139.0 |
| AVERAGE | | | | 162.8 | 129.7 |
| STANDARD DEVIATION | | | | 9.0 | 11.5 |

TABLE R11
BEARING RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | ORIENTATION | e/D | BEARING | | BEARING |
|--------------------|-------------|-----|---------|-------|------------|
| | | | ULT. | STR. | YIELD STR. |
| | | | (KSI) | | (KSI) |
| LTV | L TRANS | 2.0 | | 153.0 | 122.0 |
| | | | | 162.0 | 129.0 |
| | | | | 156.0 | 124.0 |
| MCAIR | L TRANS | 2.0 | | 170.7 | 141.3 |
| | | | | 171.1 | 140.5 |
| AVERAGE | | | | 162.6 | 131.4 |
| STANDARD DEVIATION | | | | 8.3 | 9.1 |

TABLE R12
FRACTURE TOUGHNESS RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | ORIENTATION | KIC (KSI in ^{0.5}) | Kq (KSI in ^{0.5}) | COMMENT |
|-----------|--------------------|---------------------------------|--------------------------------|---------|
| LTV | L-T | 24.1 | | VALID |
| | | 22.4 | | VALID |
| | | 21.7 | | VALID |
| AIR FORCE | L-T | 45.3 | | VALID |
| | | 46.9 | | VALID |
| | | 44.1 | | VALID |
| MCAIR | L-T | 29.4 | | VALID |
| | | 29.0 | | VALID |
| | AVERAGE | 32.9 | | |
| | STANDARD DEVIATION | 10.8 | | |

TABLE R13
FRACTURE TOUGHNESS RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | ORIENTATION | KIC (KSI in ^{0.5}) | Kq (KSI in ^{0.5}) | COMMENT |
|-----------|--------------------|---------------------------------|--------------------------------|---------|
| LTV | T-L | | 38.5 | (1) |
| | | | 36.1 | (1) |
| | | | 42.2 | (1) |
| AIR FORCE | T-L | 26.7 | | VALID |
| | | 27.2 | | VALID |
| MCAIR | T-L | 18.5 | | VALID |
| | | 18.8 | | VALID |
| | AVERAGE | 22.8 | 38.9 | |
| | STANDARD DEVIATION | 4.8 | 3.1 | |

(1): INVALID DUE TO UNSYMMETRIC CRACK FRONT CURVATURE

TABLE R14
FRACTURE TOUGHNESS RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | ORIENTATION | KIC (KSI in ^{0.5}) | Kq (KSI in ^{0.5}) | COMMENT |
|---------|--------------------|---------------------------------|--------------------------------|----------------|
| MCAIR | S-T | 20.5 21.2 | | VALID VALID |
| | AVERAGE | 20.9 | | |
| | STANDARD DEVIATION | 0.5 | | |

TABLE R15
FRACTURE TOUGHNESS RESULTS FOR
ALCOA CW67 EXTRUSION

| COMPANY | ORIENTATION | KIC (KSI in ^{0.5}) | Kq (KSI in ^{0.5}) | COMMENT |
|---------|--------------------|---------------------------------|--------------------------------|---------|
| MCAIR | S-L | 33.0 | | VALID |
| | AVERAGE | 33.0 | | |
| | STANDARD DEVIATION | 0.0 | | |

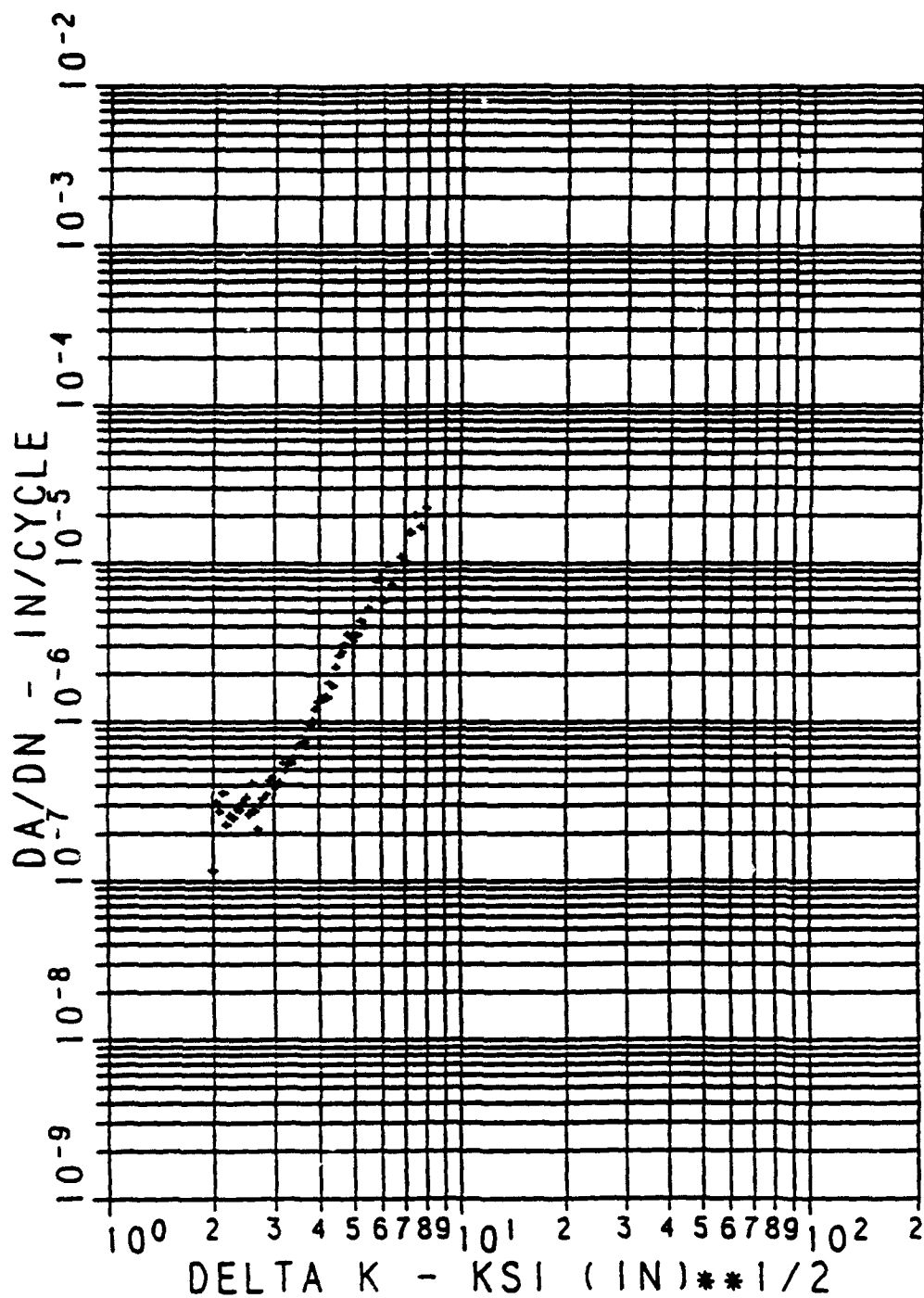
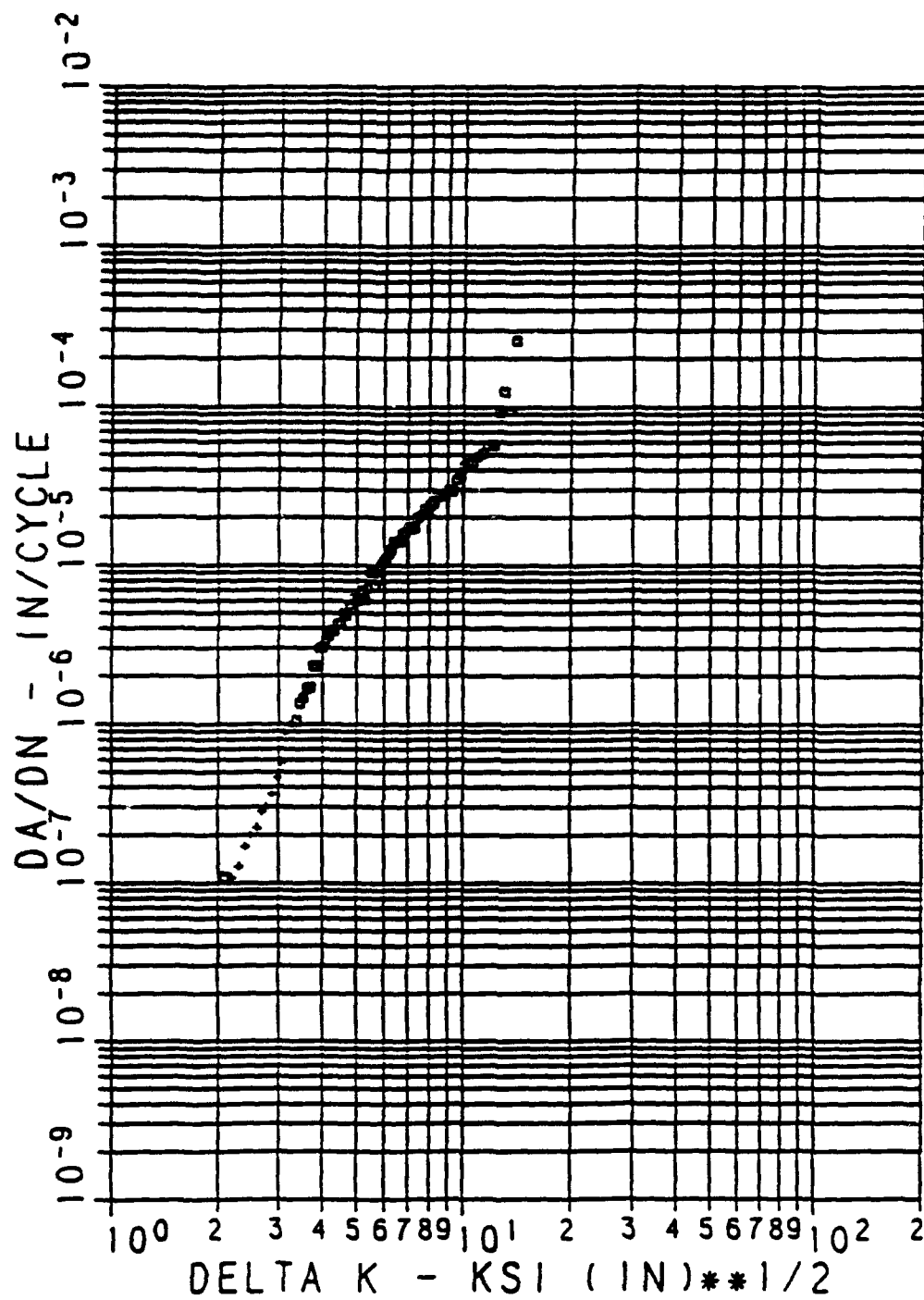


FIGURE R1. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion
 (L-T Orientation, R=0.1, Lab Air and Room Temperature).
 McDonnell Aircraft Company.



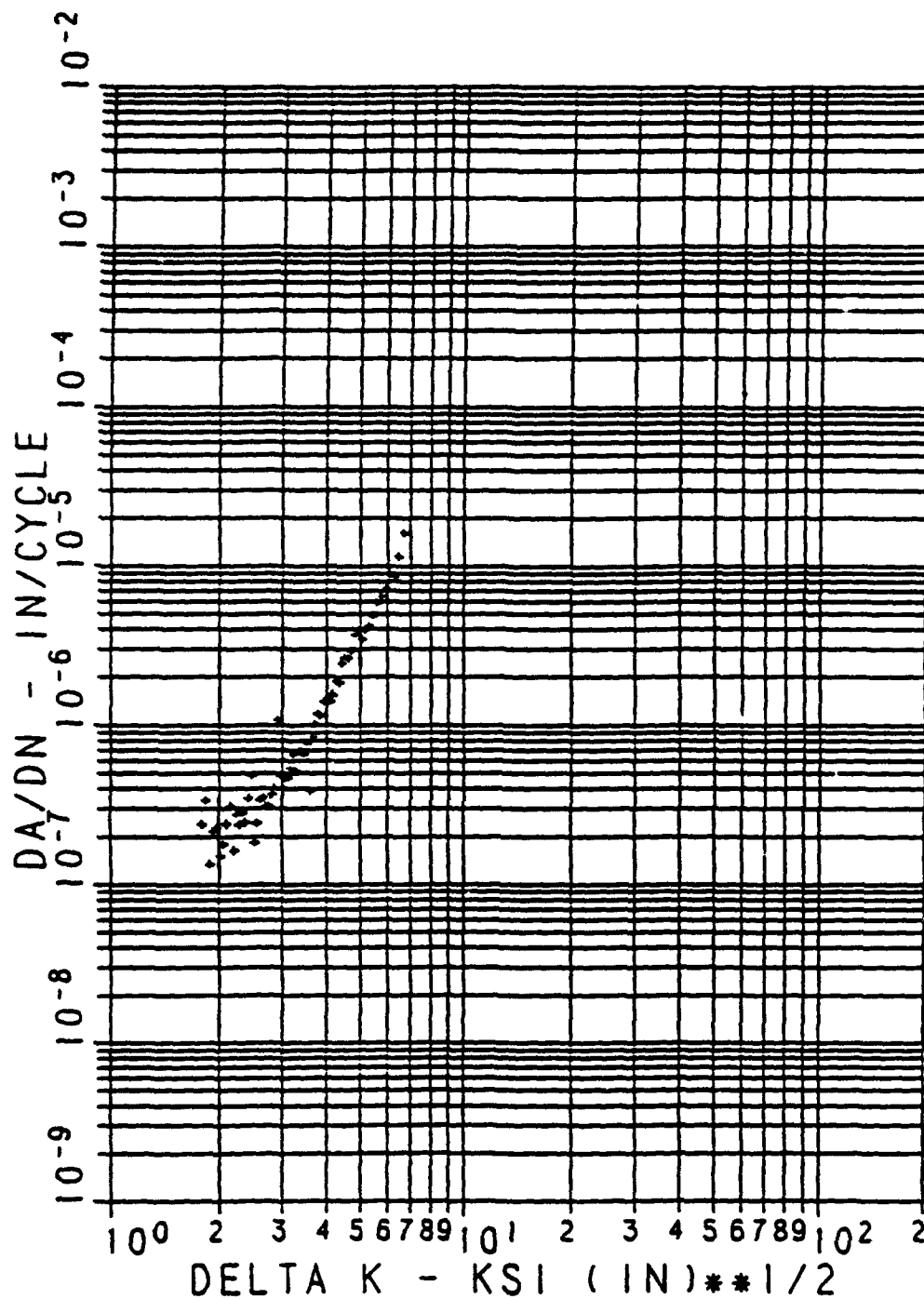


FIGURE R3. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion
(T-L Orientation, R=0.1, Lab Air and Room Temperature).
McDonnell Aircraft Company.

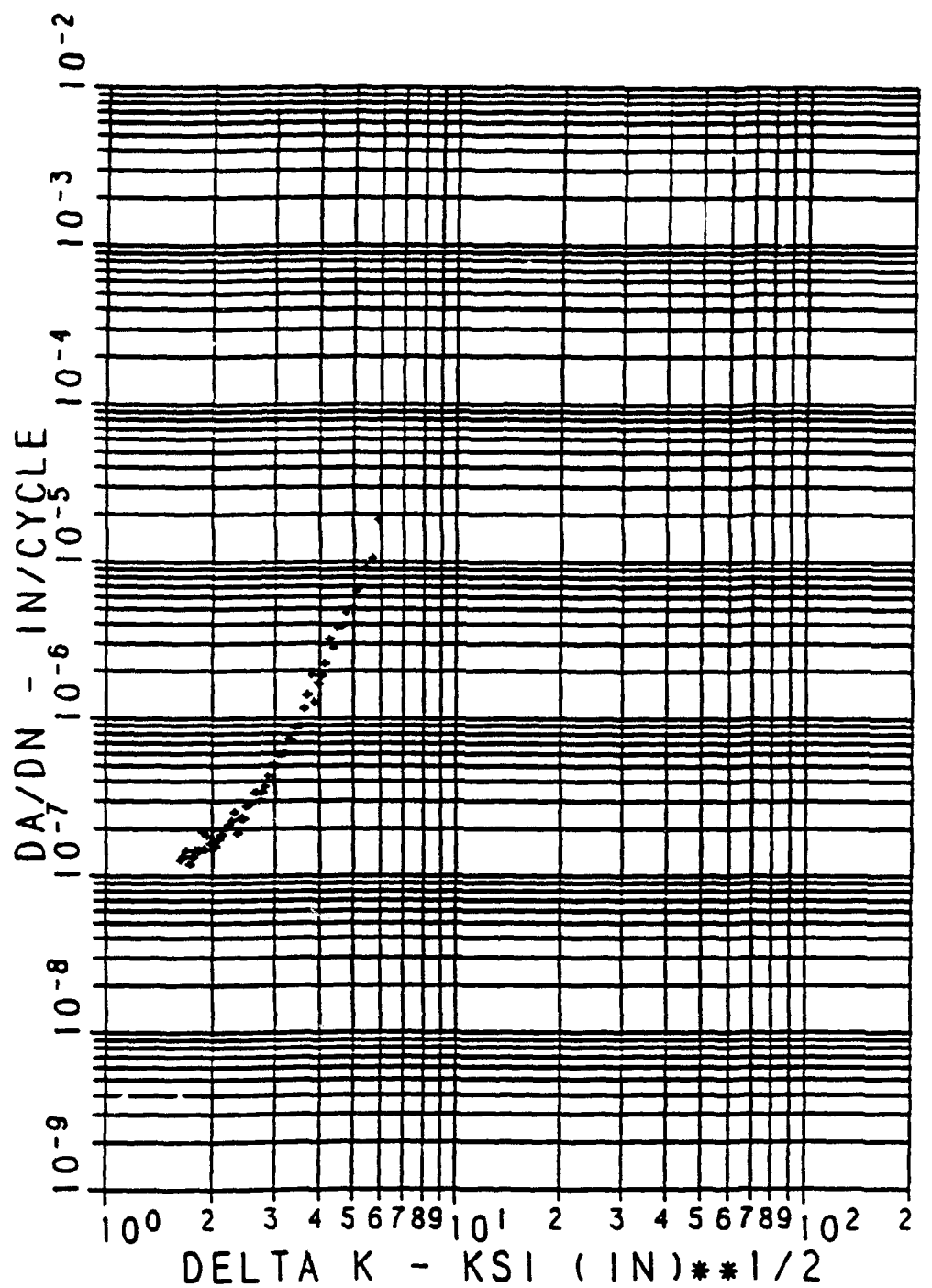


FIGURE R4. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion (T-L Orientation, $R=0.33$, Lab Air and Room Temperature). McDonnell Aircraft Company.

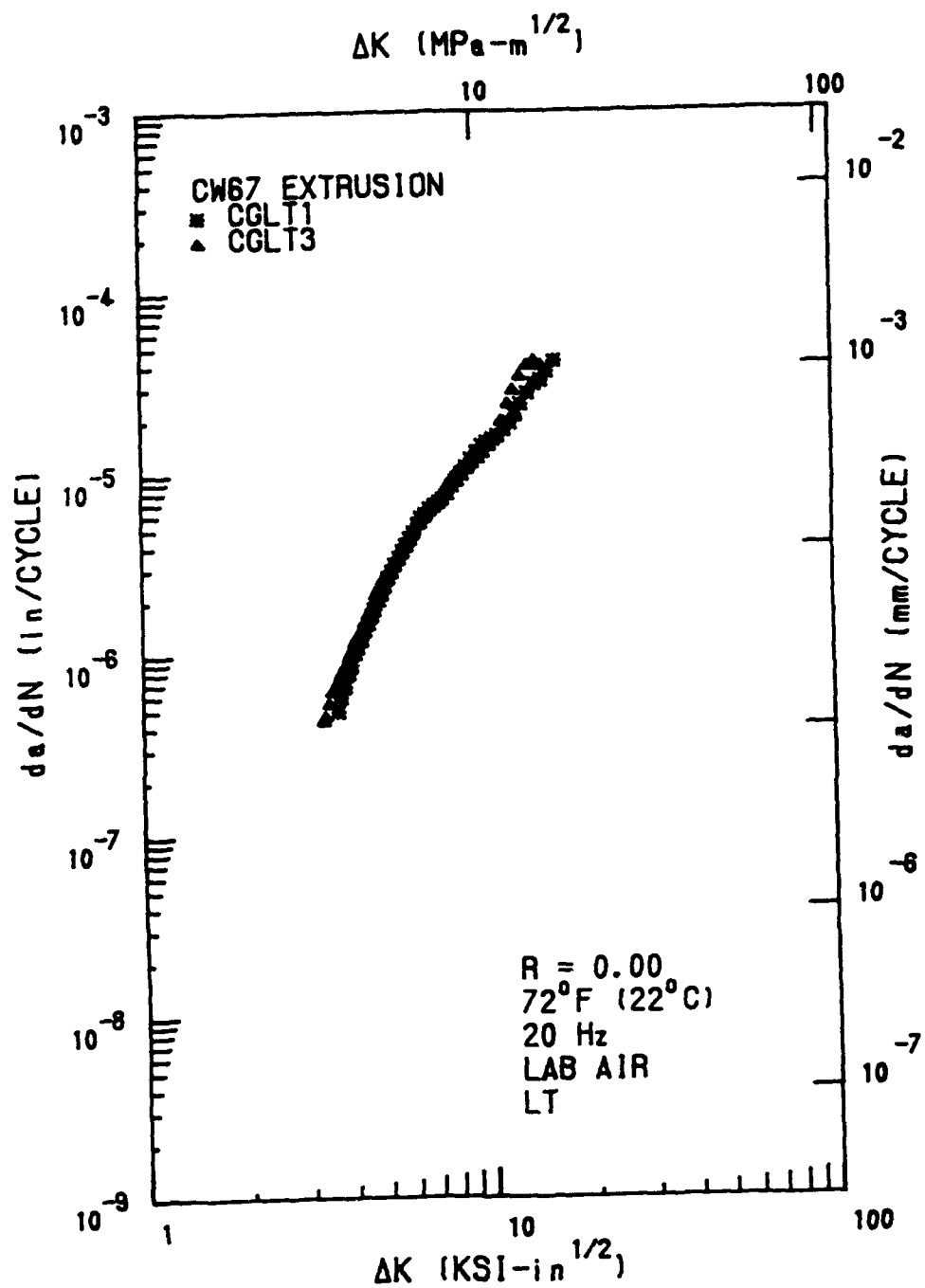


FIGURE R5. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion
 (L-T Orientation).
 Air Force.

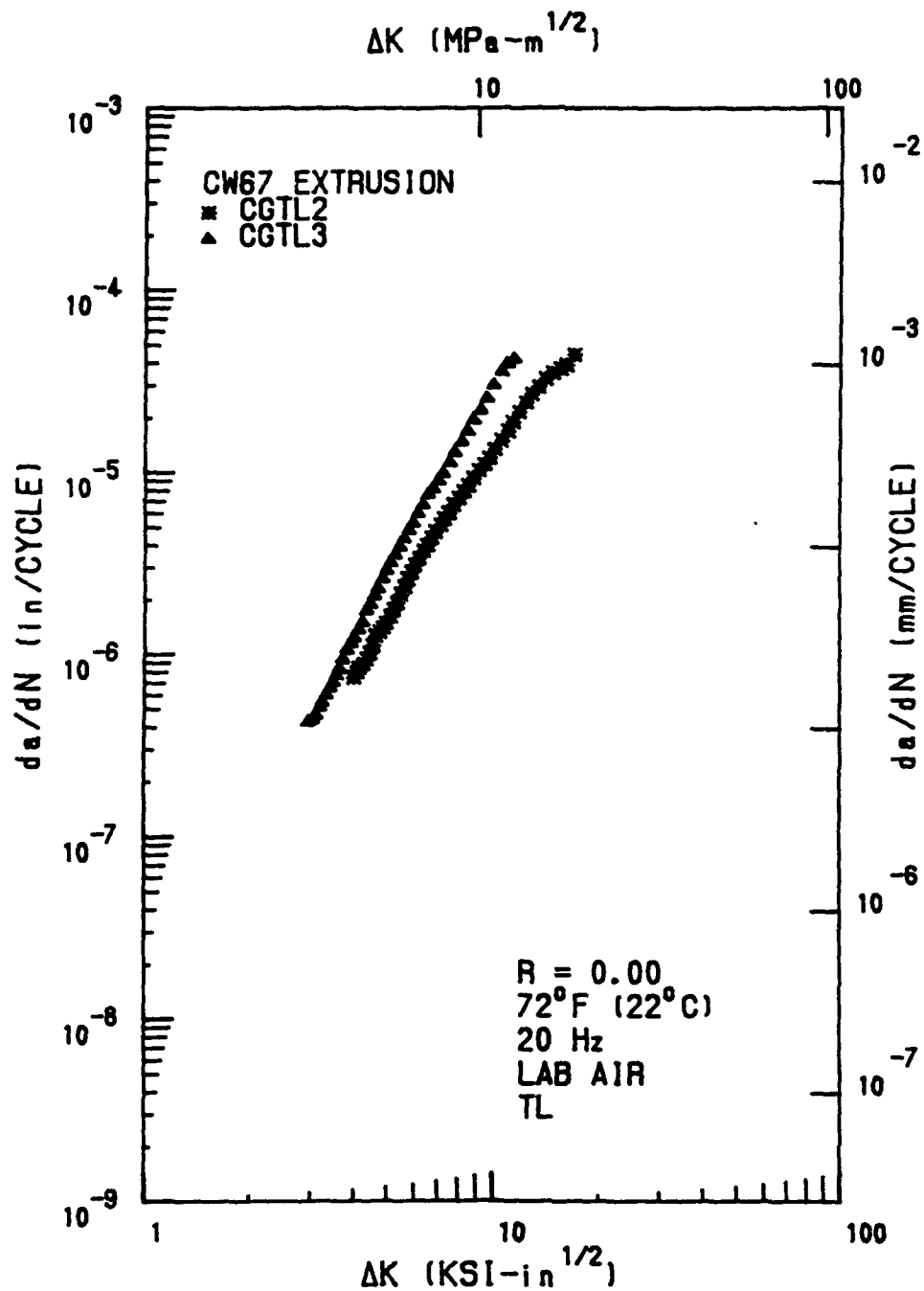


FIGURE R6. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion
 (T-L Orientation).
 Air Force.

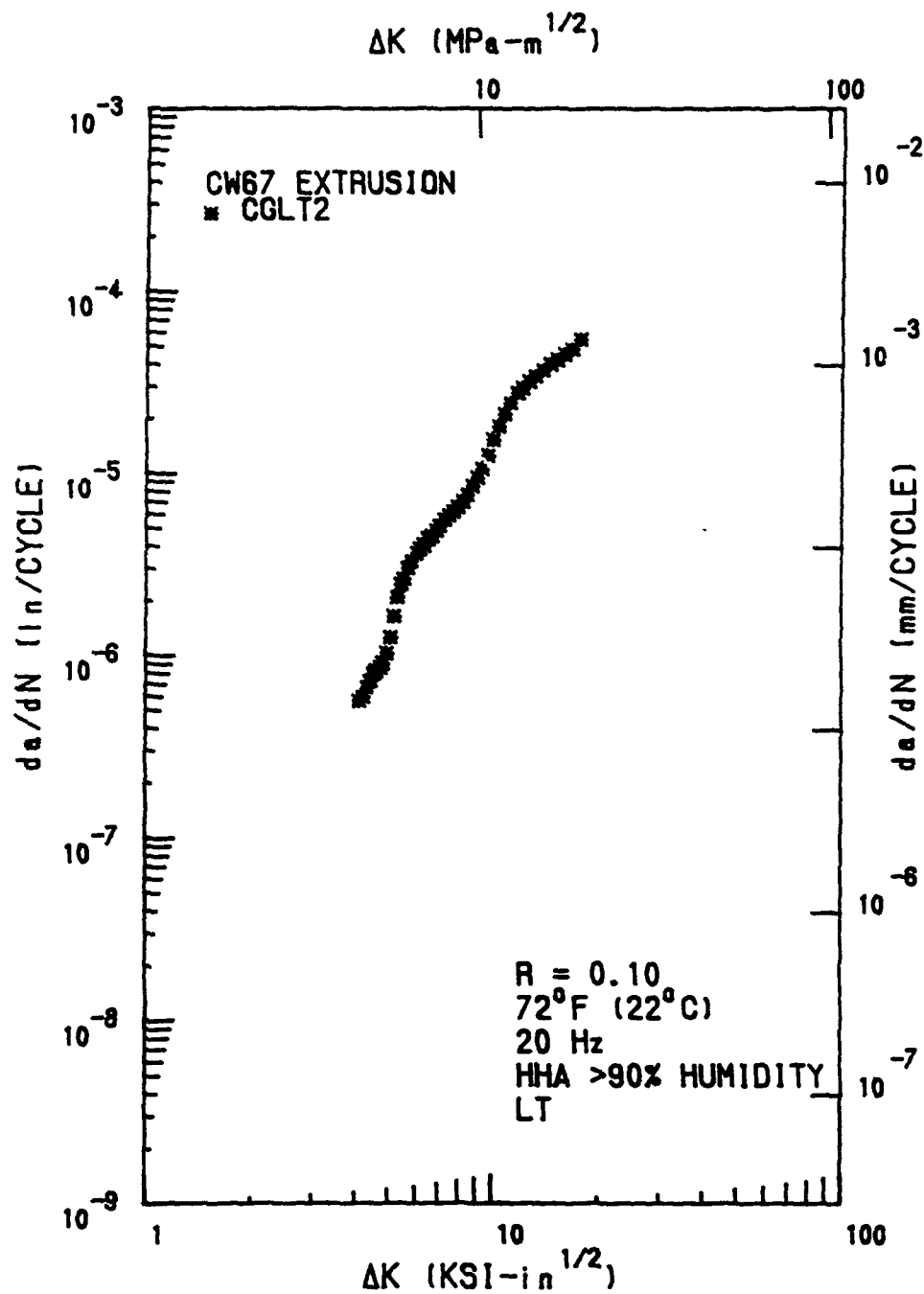


FIGURE R7. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion
 (L-T Orientation and High Humidity).
 Air Force.

SPECIMEN GLT-1

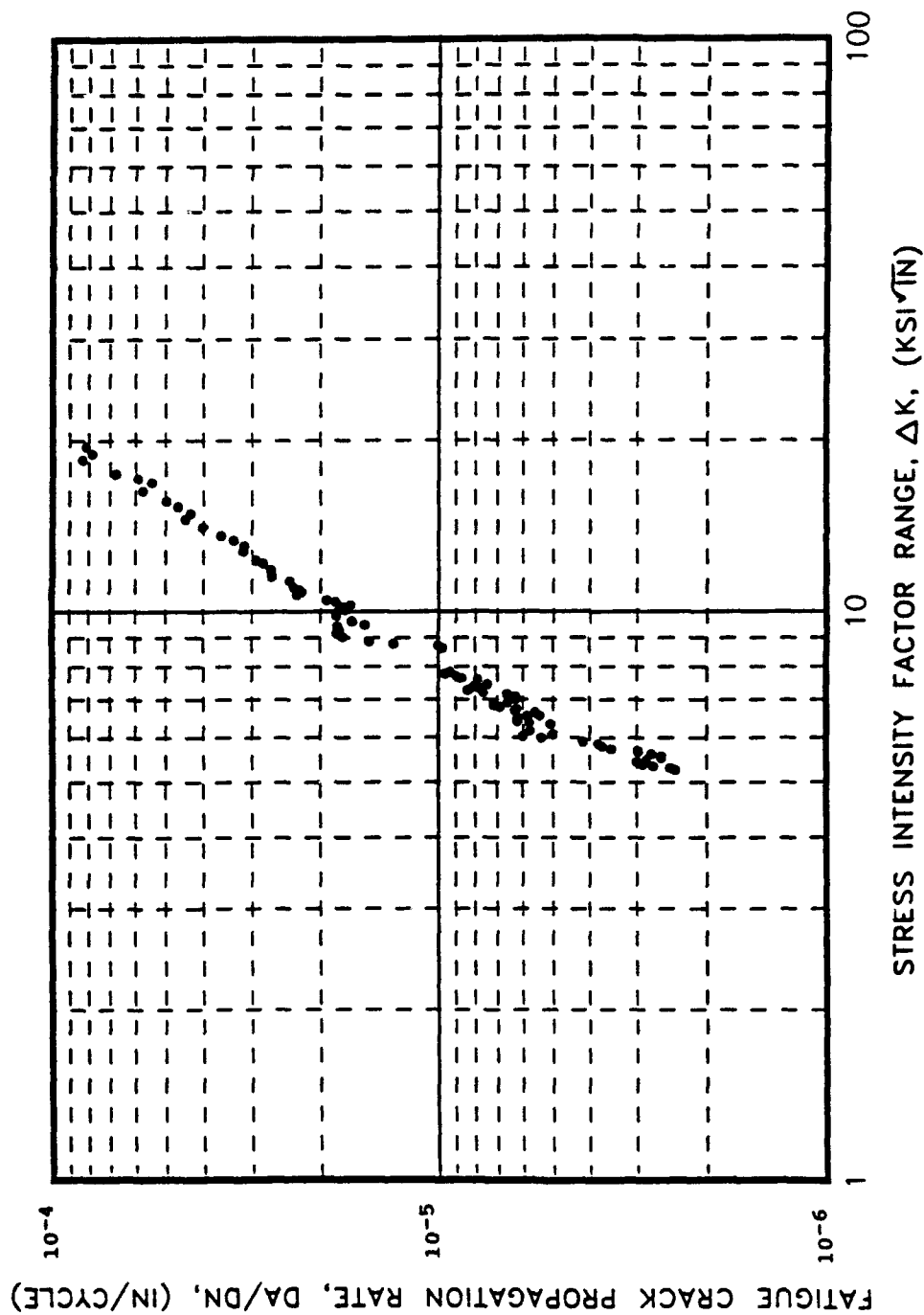


FIGURE R8. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion. (L-T Orientation, Specimen GLT-1).
LTV.

SPECIMEN GLT-2

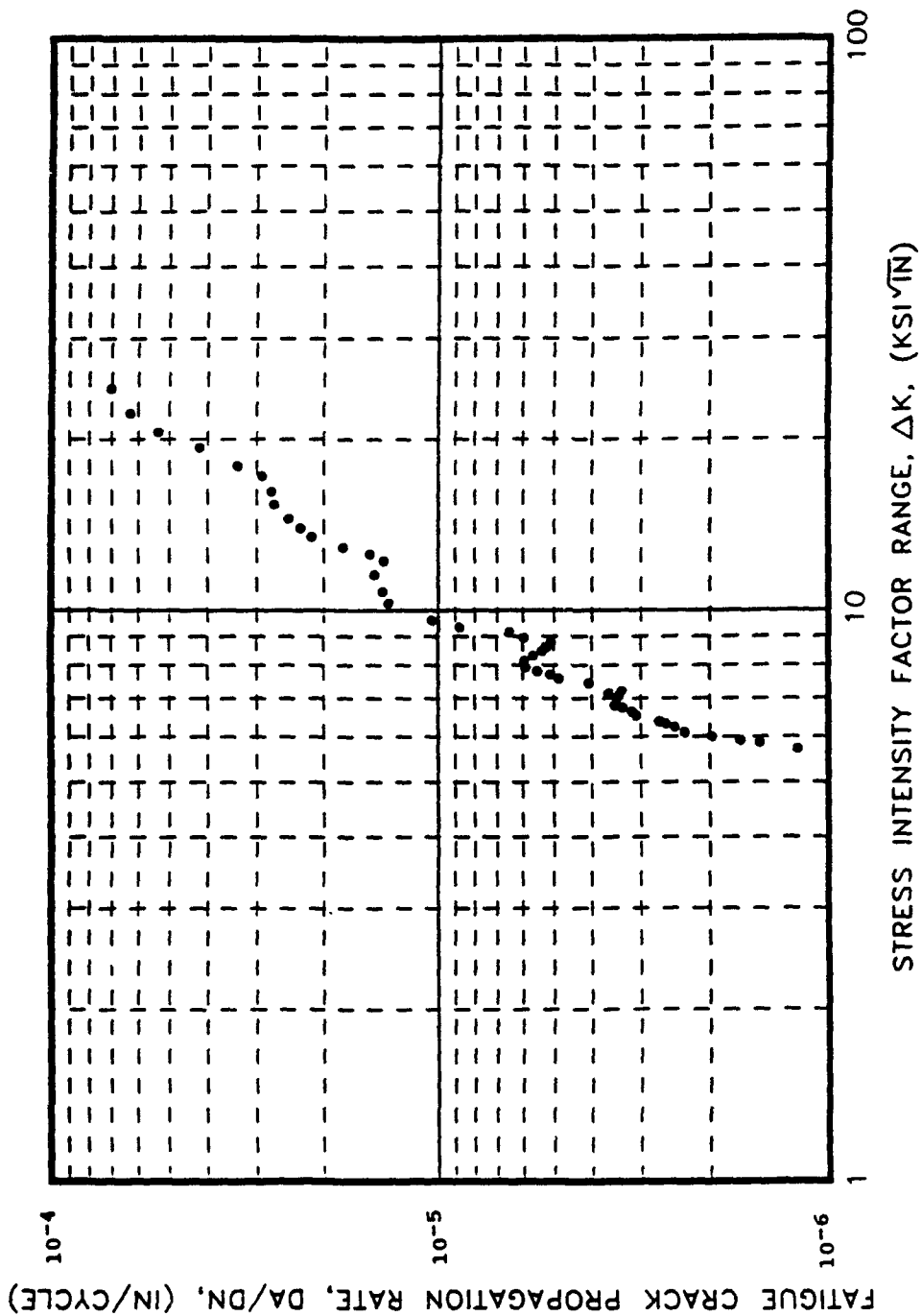


FIGURE R9. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion. (L-T Orientation, Specimen GLT-2).
LTV.

SPECIMEN GLT-3

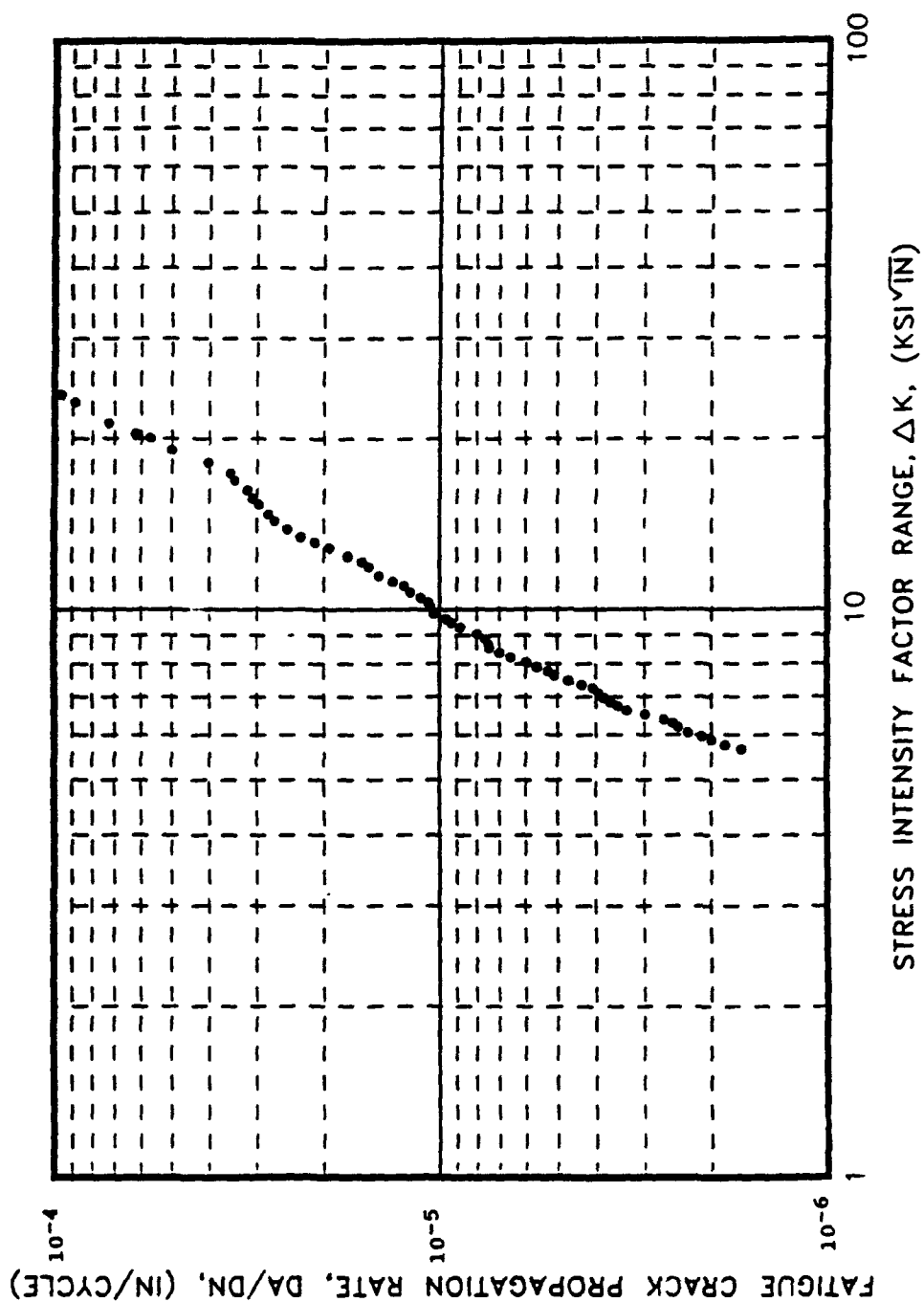


FIGURE R10. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion. (L-T Orientation, Specimen GLT-3).
LTV.

SPECIMEN GTL-1

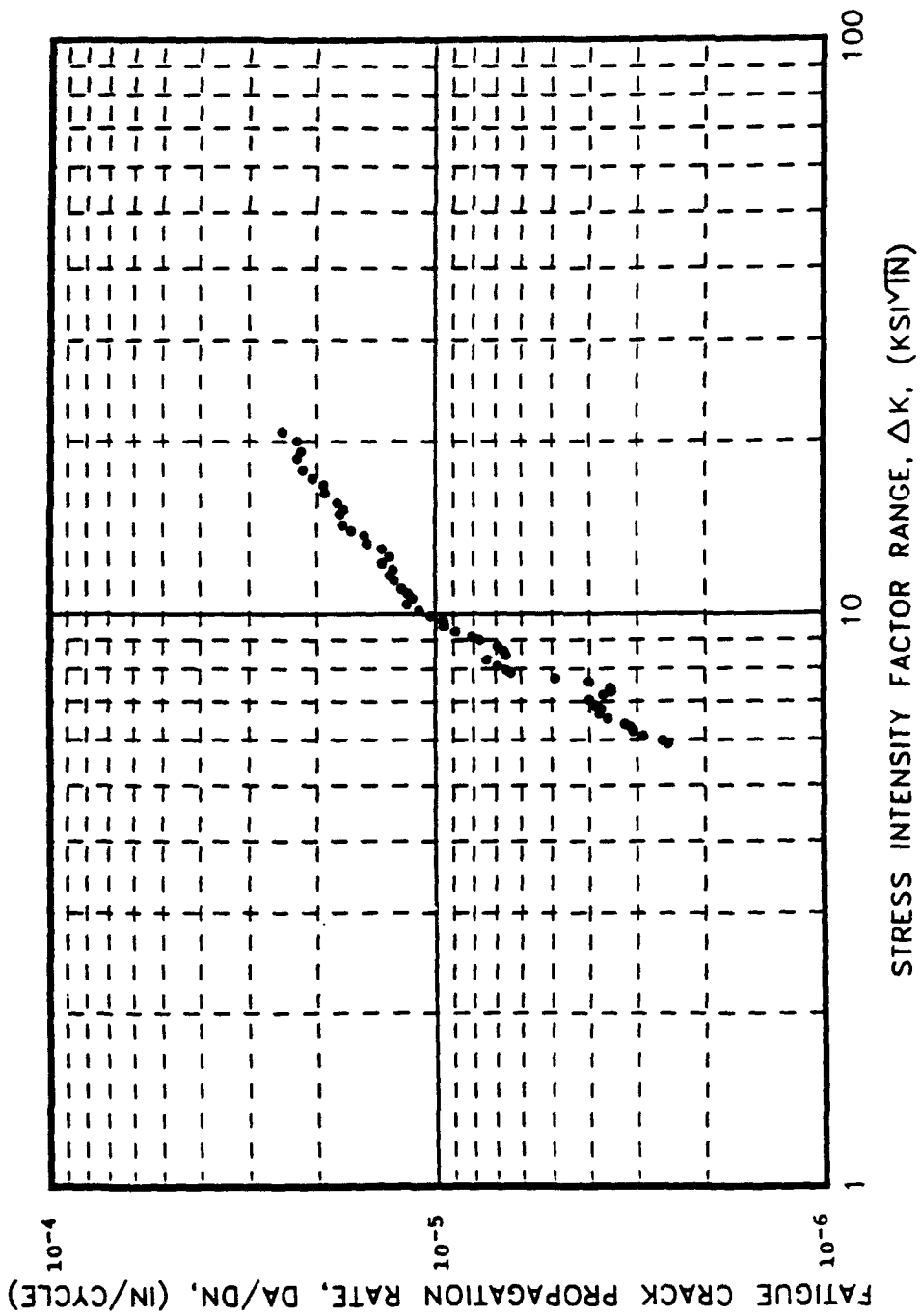


FIGURE R11. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion. (T-L Orientation, Specimen GTL-1). LTV.

SPECIMEN GTL-2

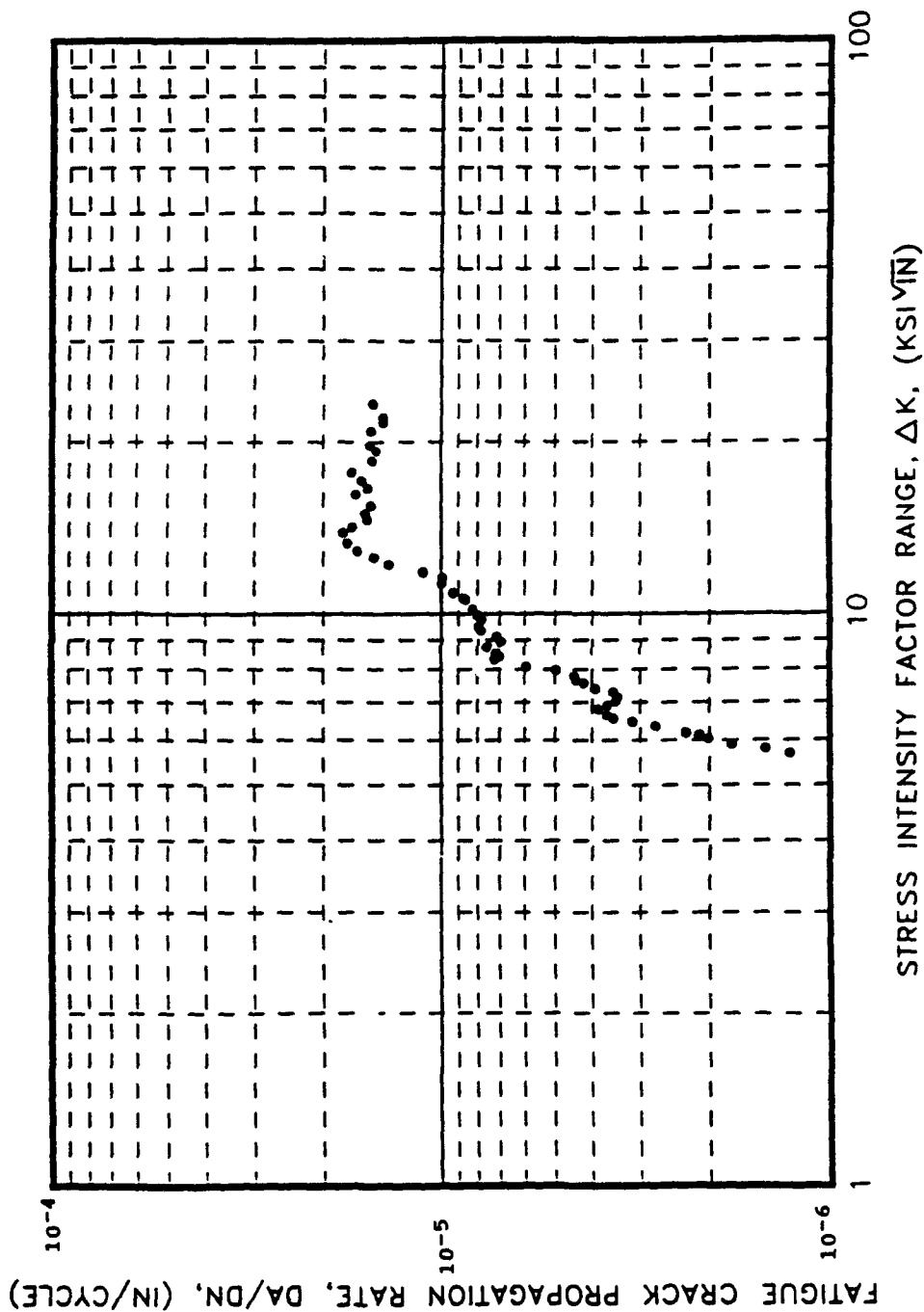


FIGURE R12. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion. (T-L Orientation, Specimen GTL-2). LTV.

SPECIMEN GTL-3

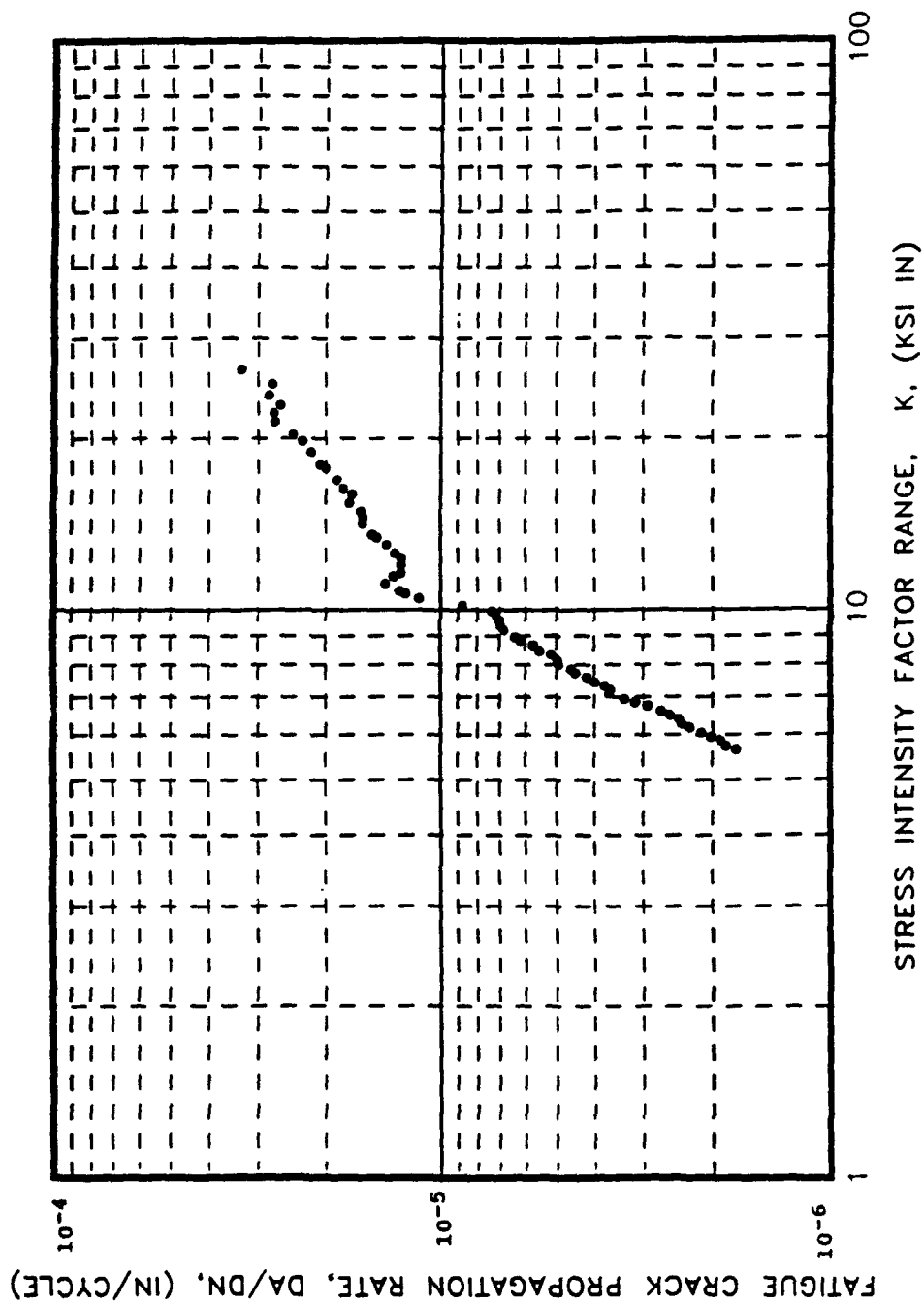


FIGURE R13. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion (T-L Orientation, Specimen GLT-3).
LTV.

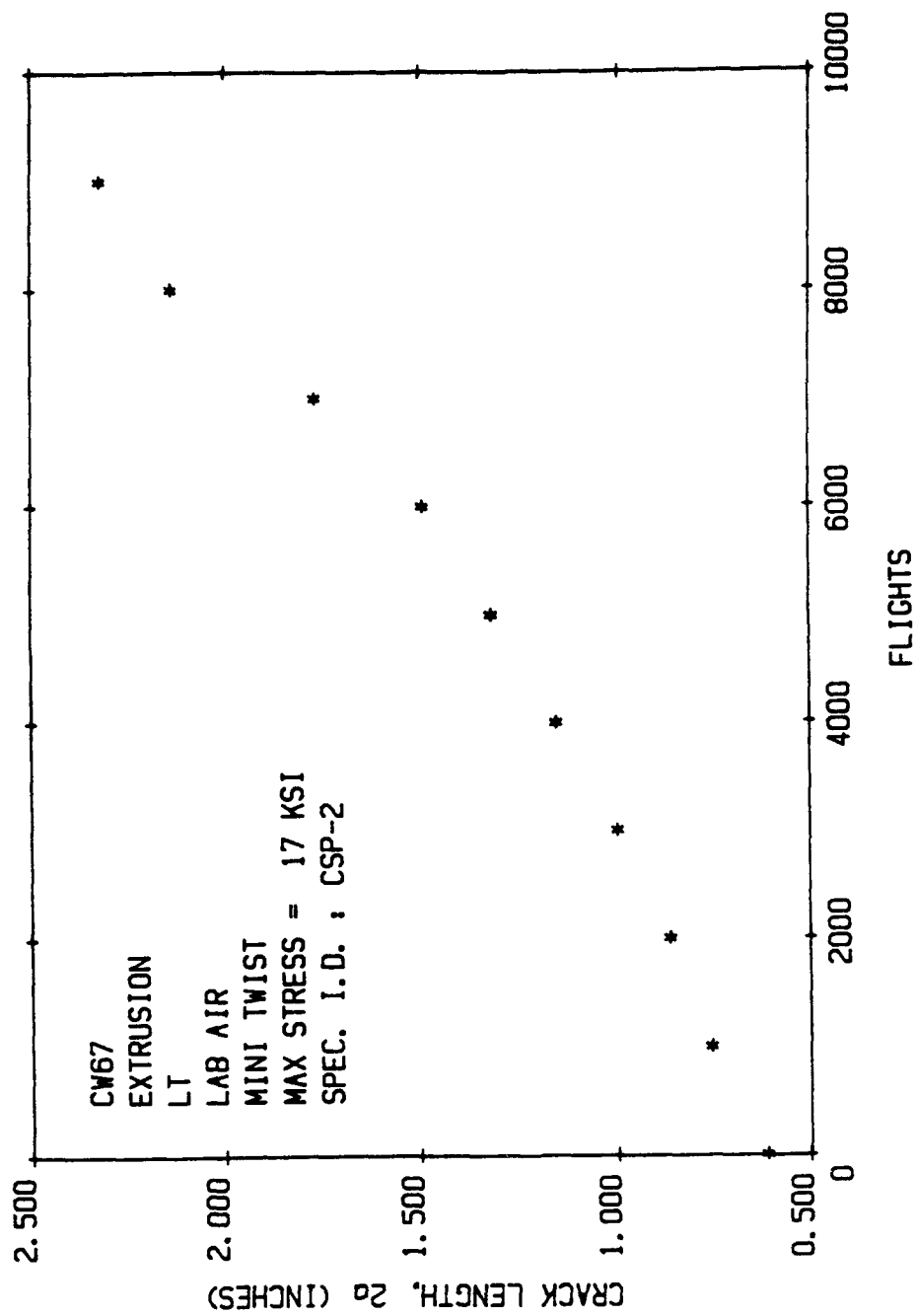


FIGURE R14. Mini-TWIST Spectrum Fatigue Cracklength vs Flights Data for CW67 Extrusion. Air Force.

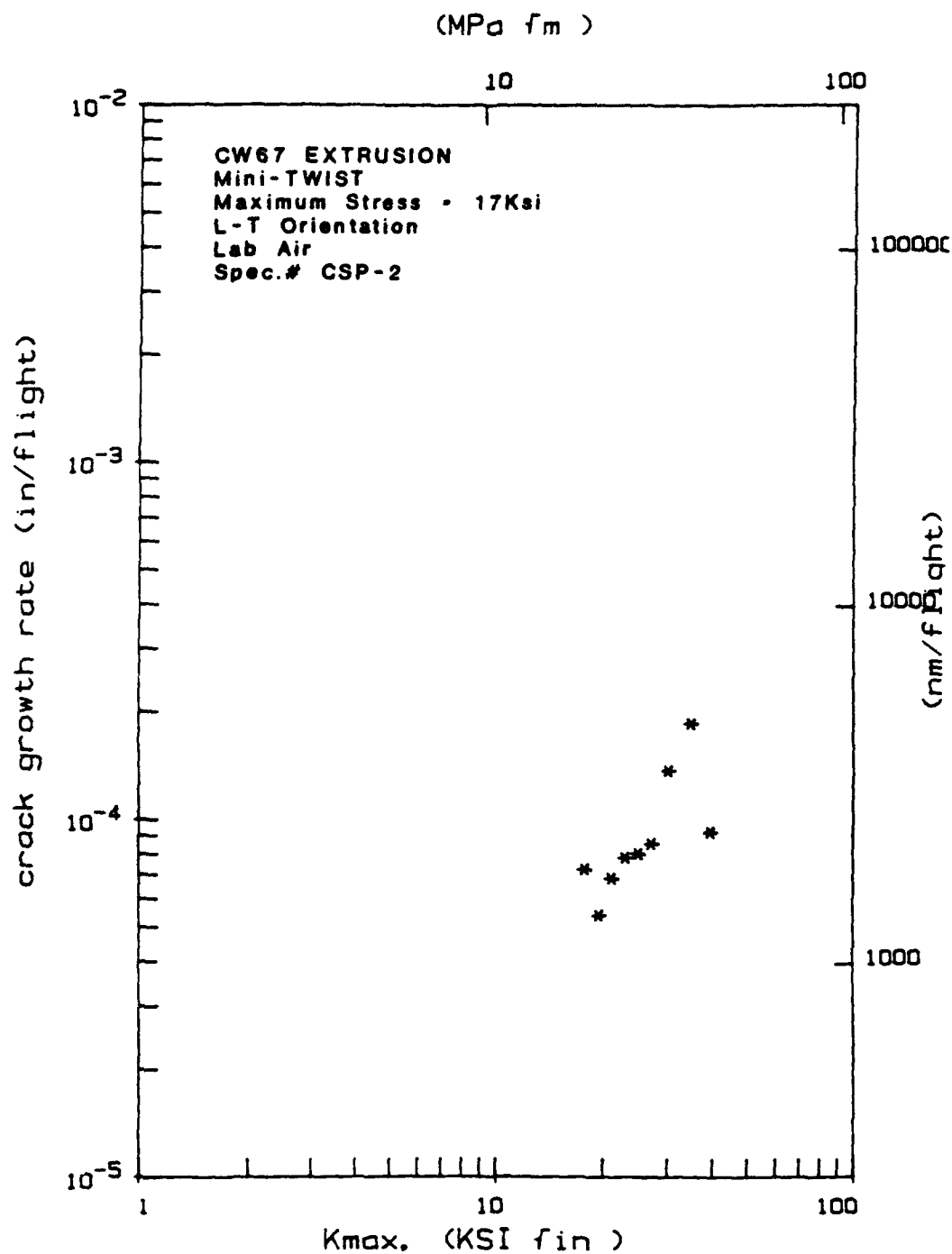


FIGURE R15. Mini-TWIST Spectrum Fatigue Crack Growth Rate Data for CW67 Extrusion.
Air Force.

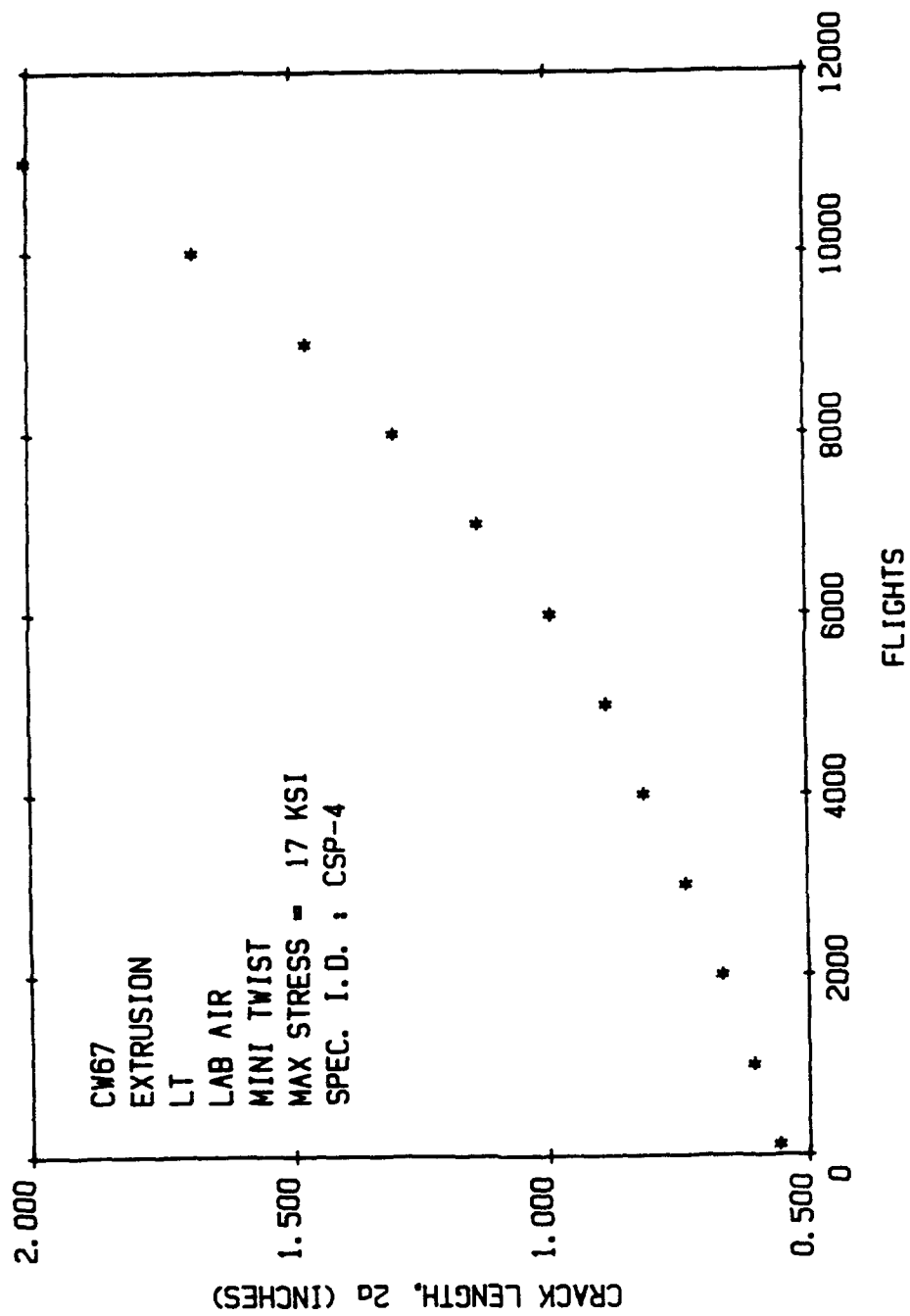


FIGURE R16. Mini-TWIST Spectrum Fatigue Crack Length vs Flights Data for CW67 Extrusion.
Air Force.

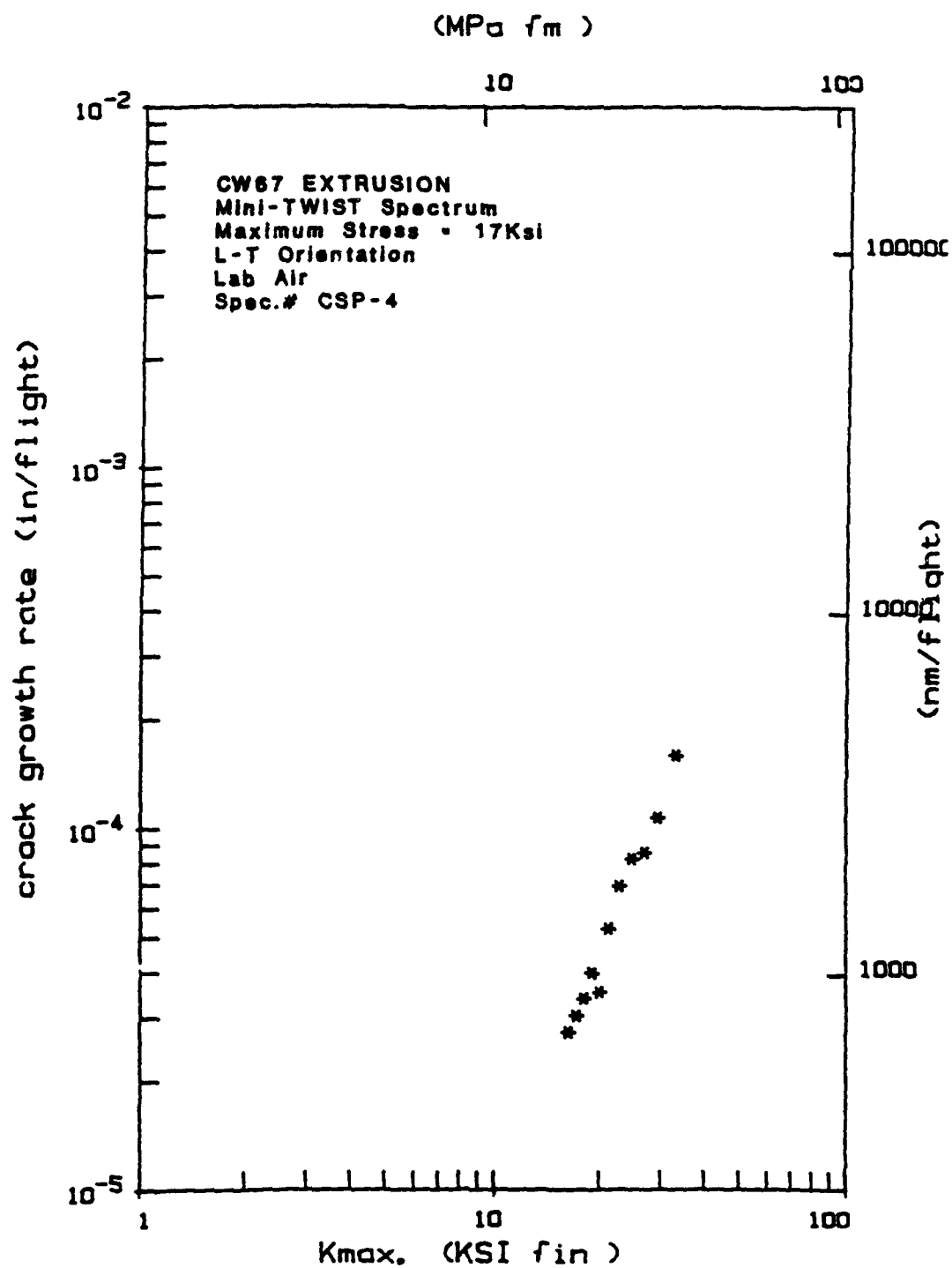


FIGURE R17. Mini-TWIST Spectrum Fatigue Crack Growth Rate Data for CW67
 Extrusion.
 Air Force.

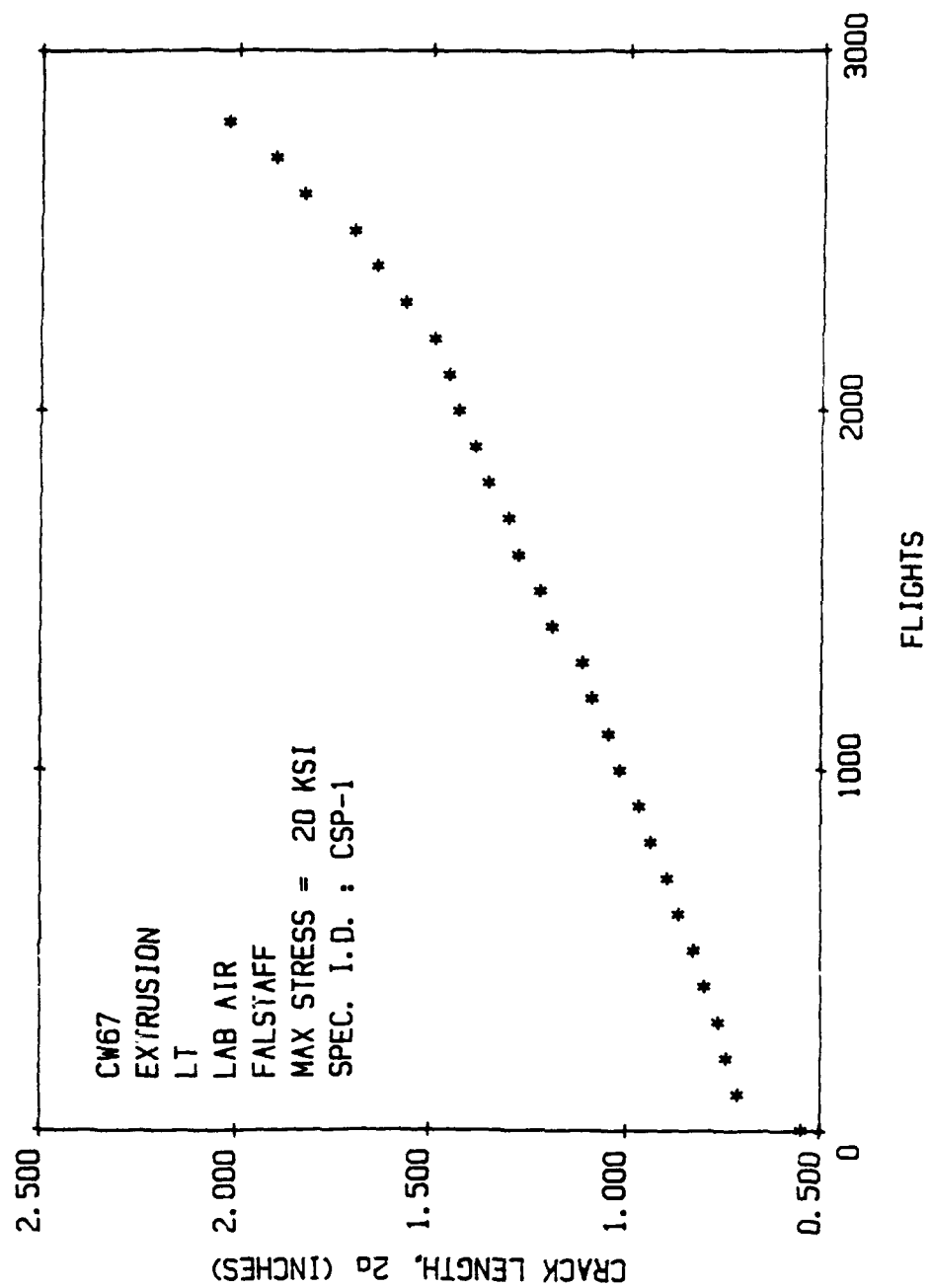


FIGURE R18. FALSTAFF Spectrum Fatigue Crack Length vs Flights.
Air Force.

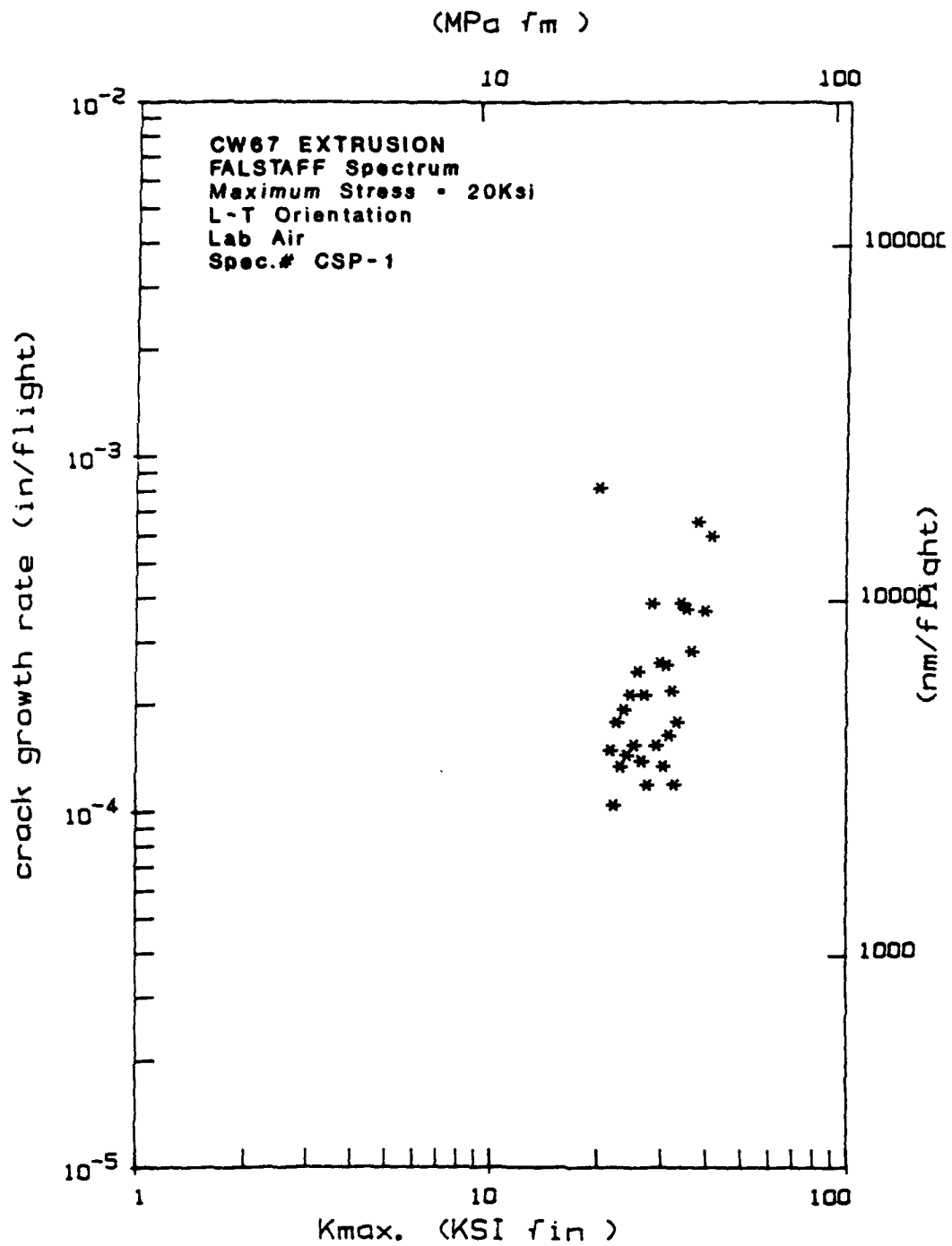


FIGURE R19. FALSTAFF Spectrum Fatigue Crack Growth Rate Data for CW67
 Extrusion.
 Air Force.

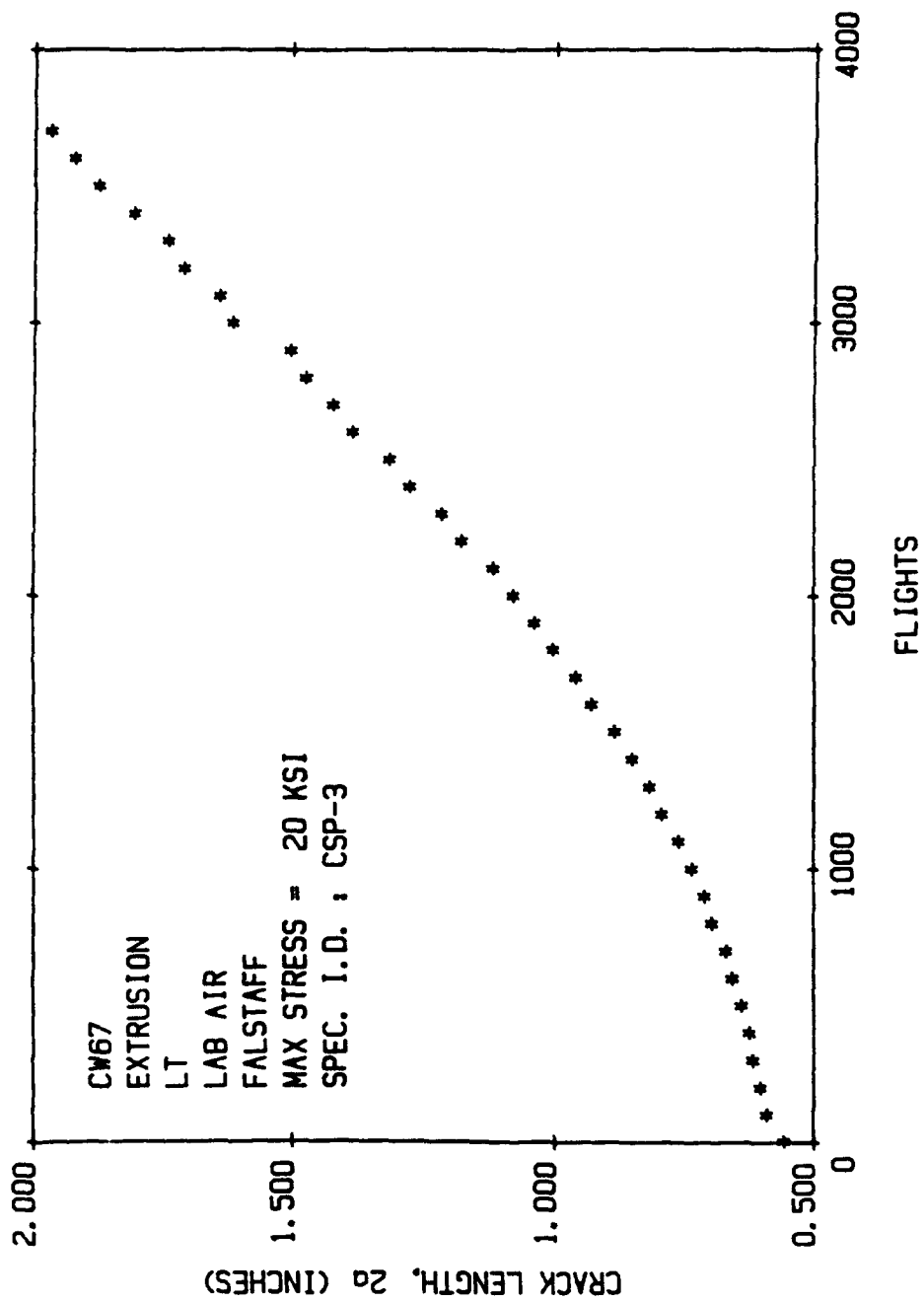


FIGURE R20. FALSTAFF Spectrum Fatigue Crack Length vs Flights.
Air Force.

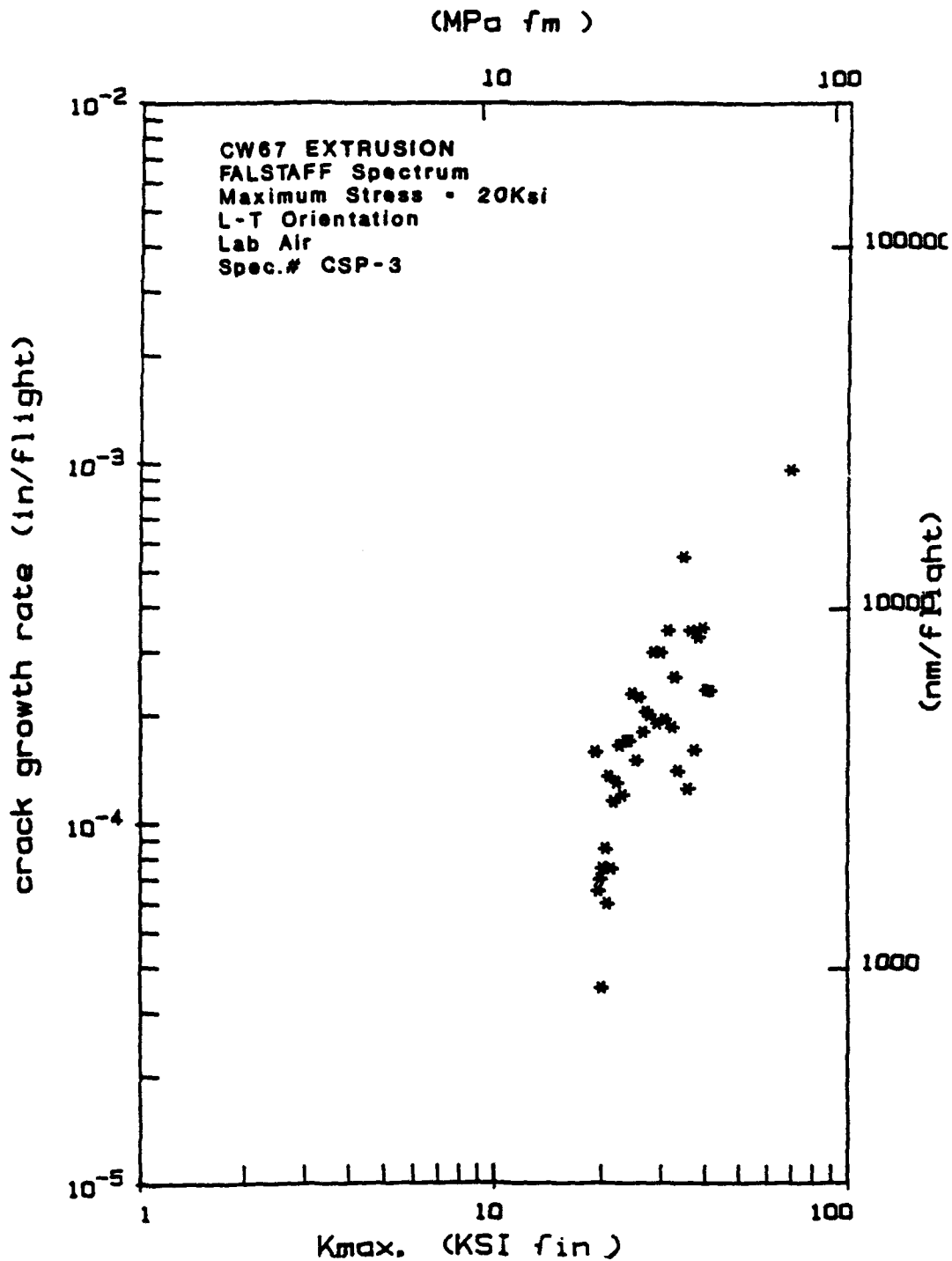


FIGURE R21. FALSTAFF Spectrum Fatigue Crack Growth Rate Data for CW67
 Extrusion.
 Air Force.

APPENDIX S

CW67 HAND FORGING
2.5"X6"X18"

TABLE S1
TENSILE RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | E (MSI) | | |
|----------------------------------|-----------------------------|------------------|-------------------------------|----------------------------|--------------|-----------|------------|------|--|
| MARTIN MARIETTA, LOUISIANA | RT | LONG | 87.2 | 84.0 | 13.0 | 29.6 | | | |
| | | | 83.1 | 75.9 | 15.0 | 39.7 | | | |
| | | | 85.0 | 82.5 | 14.0 | 27.6 | | | |
| AIR FORCE | RT | LONG | 88.0 | 83.6 | 13.0 | 39.7 | | | |
| | | | 82.2 | 78.6 | 13.8 | 47.9 | | | |
| | | | 85.4 | 80.7 | 12.7 | 34.5 | | | |
| | | | 84.6 | 80.1 | 12.1 | 46.9 | | | |
| | | | AVERAGE | | 85.1 | 80.8 | 13.4 | 38.0 | |
| | | | STANDARD DEVIATION | | 2.1 | 2.9 | 1.0 | 7.9 | |

TABLE S2
TENSILE RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | E (MSI) |
|----------------------------------|-----------------------------|--------------------|-------------------------------|----------------------------|--------------|-----------|------------|
| MARTIN MARIETTA, LOUISIANA | RT | L TRANS | 79.1 | 73.4 | 12.0 | 17.6 | |
| | | | 78.8 | 73.0 | 14.0 | 25.5 | |
| | | | 79.4 | 74.0 | 17.0 | 42.5 | |
| AIR FORCE | RT | L TRANS | 82.4 | 77.2 | 13.9 | 40.1 | |
| | | | 83.0 | 77.0 | 10.2 | 25.3 | |
| | | | 83.2 | 77.2 | 13.5 | 38.9 | |
| | | | 82.3 | 75.4 | 13.0 | 32.6 | |
| | | AVERAGE | 81.2 | 75.3 | 13.4 | 31.8 | |
| | | STANDARD DEVIATION | 2.0 | 1.9 | 2.1 | 9.3 | |

TABLE S3
TENSILE RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | TEST TEMP (DEGREES F) | ORIENT- ATION | ULTIMATE STRENGTH (KSI) | YIELD STRENGTH (KSI) | ELONG (%) | RA (%) | E (MSI) |
|------------------------|-----------------------------|--------------------|-------------------------------|----------------------------|--------------|-----------|------------|
| MARTIN | RT | S TRANS | 78.7 | 72.4 | 12.0 | 32.7 | |
| MARIETTA, LOUISIANA | | | 77.9 | 71.5 | 11.0 | 32.7 | |
| | | | 77.5 | 70.8 | 14.0 | 36.0 | |
| AIR FORCE | RT | S TRANS | 85.7 | 79.3 | 6.8 | 18.1 | |
| | | | 43.8 | 43.8 | 9.1 | 23.1 | |
| | | AVERAGE | 72.7 | 67.6 | 10.6 | 28.5 | |
| | | STANDARD DEVIATION | 16.5 | 13.7 | 2.7 | 7.6 | |

TABLE S4
COMPRESSION RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | TEST TEMPERATURE (DEGREES F) | ORIENTATION | COMPRESSIVE YIELD STRENGTH (KSI) | COMPRESSIVE MODULUS (MSI) |
|------------------------|------------------------------------|--------------------|--|---------------------------------|
| MARTIN | RT | LONG | 82.9 | 10.6 |
| MARIETTA, LOUISIANA | | | 81.9 | 10.6 |
| | | | 81.4 | 10.6 |
| AIR FORCE | RT | LONG | 81.0 | |
| | | | 79.4 | |
| | | | 77.3 | |
| | | | 76.4 | |
| | | AVERAGE | 80.0 | 10.6 |
| | | STANDARD DEVIATION | 2.4 | 0.0 |

TABLE S5
COMPRESSION RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | TEST TEMPERATURE (DEGREES F) | ORIENTATION | COMPRESSIVE YIELD STRENGTH (KSI) | COMPRESSIVE MODULUS (MSI) |
|------------------------|------------------------------------|--------------------|--|---------------------------------|
| MARTIN | RT | L TRANS | 78.6 | 10.8 |
| MARIETTA, LOUISIANA | | | 78.8 | 11.0 |
| | | | 79.6 | 11.0 |
| AIR FORCE | RT | L TRANS | 81.6 | |
| | | | 82.5 | |
| | | | 81.5 | |
| | | | 80.0 | |
| | | AVERAGE | 80.4 | 10.9 |
| | | STANDARD DEVIATION | 1.5 | 0.1 |

TABLE S6
COMPRESSION RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | TEST TEMPERATURE (DEGREES F) | ORIENTATION | COMPRESSIVE YIELD STRENGTH (KSI) | COMPRESSIVE MODULUS (MSI) |
|-----------|------------------------------------|--------------------|--|---------------------------------|
| MARTIN | RT | S TRANS | 80.1 | 10.7 |
| MARIETTA, | | | 82.1 | 10.8 |
| LOUISIANA | | | 80.2 | 10.8 |
| | | AVERAGE | 80.8 | 10.8 |
| | | STANDARD DEVIATION | 1.1 | 0.1 |

TABLE S7
PIN SHEAR RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | ORIENTATION | SHEAR STRENGTH (KSI) |
|-----------|--------------------|-------------------------|
| AIR FORCE | LONG | 50.0 |
| | | 50.1 |
| | | 50.2 |
| | | 49.8 |
| | AVERAGE | 50.0 |
| | STANDARD DEVIATION | 0.2 |

TABLE S8
PIN SHEAR RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | ORIENTATION | SHEAR STRENGTH (KSI) |
|-----------|--------------------|-------------------------|
| AIR FORCE | L TRANS | 49.2 |
| | | 49.8 |
| | | 49.5 |
| | | 49.7 |
| | AVERAGE | 49.5 |
| | STANDARD DEVIATION | 0.3 |

TABLE S9
BEARING RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | ORIENTATION | e/D | BEARING ULT. STRENGTH (KSI) | BEARING YIELD STRENGTH (KSI) |
|--------------------|--------------------|-------|-----------------------------------|------------------------------------|
| AIR FORCE | LONG | 1.5 | 137.9 | 122.3 |
| | | | 137.3 | 118.8 |
| | | | 131.2 | 118.9 |
| | AVERAGE | | 135.5 | 120.0 |
| | STANDARD DEVIATION | | 3.7 | 2.0 |
| | L TRANS | 1.5 | 136.0 | 123.0 |
| | | | 137.4 | 130.5 |
| | | | 132.4 | 128.2 |
| | AVERAGE | | 135.2 | 127.2 |
| | STANDARD DEVIATION | | 2.6 | 3.8 |
| | LONG | 2.0 | 165.5 | 118.0 |
| | | | 164.9 | 77.8 |
| | | | 162.7 | 104.1 |
| | AVERAGE | | 164.3 | 100.0 |
| | STANDARD DEVIATION | | 1.5 | 20.5 |
| L TRANS | 2.0 | 166.4 | 103.1 | |
| | | 168.1 | 117.5 | |
| | | 162.1 | 99.9 | |
| AVERAGE | | 165.5 | 106.8 | |
| STANDARD DEVIATION | | 3.1 | 9.4 | |

TABLE S10
FRACTURE TOUGHNESS RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | ORIENTATION | KIC (KSI in ^{0.5}) | Kq (KSI in ^{0.5}) | COMMENT |
|----------------------------------|--------------------|---------------------------------|--------------------------------|--------------------------|
| MARTIN MARIETTA, LOUISIANA | L - T | 44.8 | 35.9 | VALID INVALID(1) |
| AIR FORCE | L - T | | 28.8 34.4 | INVALID(2) INVALID(2) |
| | AVERAGE | 44.8 | 33.0 | |
| | STANDARD DEVIATION | 0.0 | 3.8 | |

(1): a/W > 0.55

(2): EXCESSIVE CRACK FRONT CURVATURE

TABLE S11
FRACTURE TOUGHNESS RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | ORIENTATION | KIC (KSI in ^{0.5}) | Kq (KSI in ^{0.5}) | COMMENT |
|----------------------------------|--------------------|---------------------------------|--------------------------------|-----------------------------------|
| MARTIN MARIETTA, LOUISIANA | L - S | | 46.7 52.5 | INVALID(1) INVALID(1) VALID |
| | | 38.6 | | |
| | AVERAGE | 38.6 | 49.6 | |
| | STANDARD DEVIATION | 0.0 | 4.1 | |

(1): a/W > 0.55

TABLE S12
FRACTURE TOUGHNESS RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | ORIENTATION | KIC (KSI in ^{0.5}) | Kq (KSI in ^{0.5}) | COMMENT |
|------------------------|--------------------|---------------------------------|--------------------------------|------------|
| MARTIN | T - L | 25.0 | | VALID |
| MARIETTA, LOUISIANA | | 21.6 | | VALID |
| AIR FORCE | T - L | | 21.0 | INVALID(1) |
| | | | 18.6 | INVALID(1) |
| | | | 22.5 | INVALID(1) |
| | AVERAGE | 23.3 | 20.7 | |
| | STANDARD DEVIATION | 2.4 | 2.0 | |

(1): EXCESSIVE CRACK FRONT CURVATURE

TABLE S13
FRACTURE TOUGHNESS RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | ORIENTATION | KIC (KSI in ^{0.5}) | Kq (KSI in ^{0.5}) | COMMENT |
|------------------------|--------------------|---------------------------------|--------------------------------|------------|
| MARTIN | T - S | 21.3 | | VALID |
| MARIETTA, LOUISIANA | | | 23.5 | INVALID(1) |
| | AVERAGE | 21.3 | 23.5 | |
| | STANDARD DEVIATION | 0.0 | 0.0 | |

(1): $a/W > 0.55$

TABLE S14
FRACTURE TOUGHNESS RESULTS FOR
ALCOA CW67 FORGING

| COMPANY | ORIENTATION | KIC | Kq | COMMENT |
|-----------|--------------------|--------------|--------------|------------|
| | | (KSI in^0.5) | (KSI in^0.5) | |
| <hr/> | | | | |
| AIR FORCE | S - T | | 20.9 | INVALID(1) |
| | | | 25.3 | INVALID(1) |
| | | | 23.6 | INVALID(1) |
| | AVERAGE | | 23.3 | |
| | STANDARD DEVIATION | | 2.2 | |

(1): EXCESSIVE CRACK FRONT CURVATURE

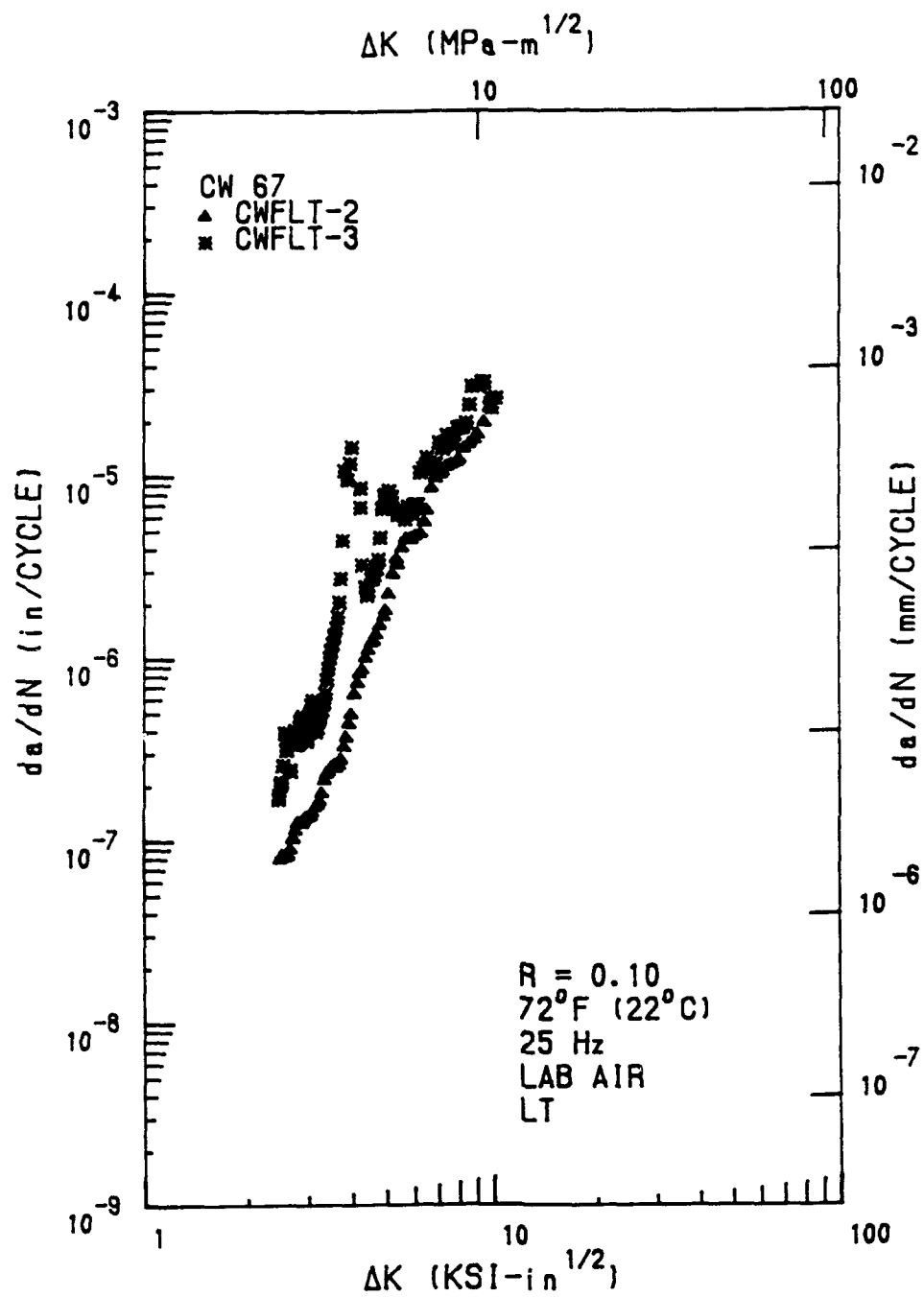


FIGURE S1. Fatigue Crack Growth Rate Data for CW67 Forging (L-T Orientation).
Air Force.

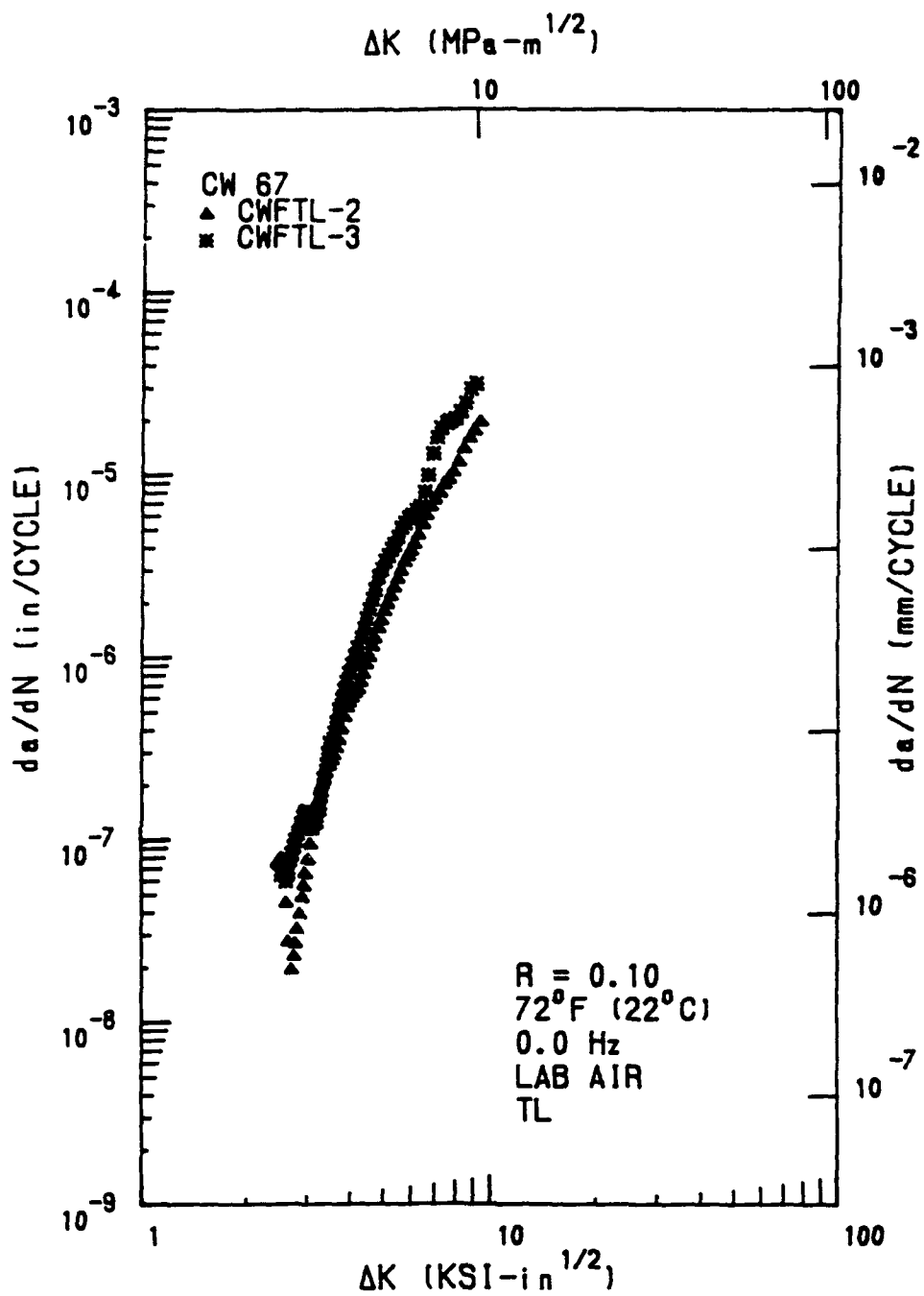


FIGURE S2. Fatigue Crack Growth Rate Data for CW67 Forging (T-L Orientation). Air Force.

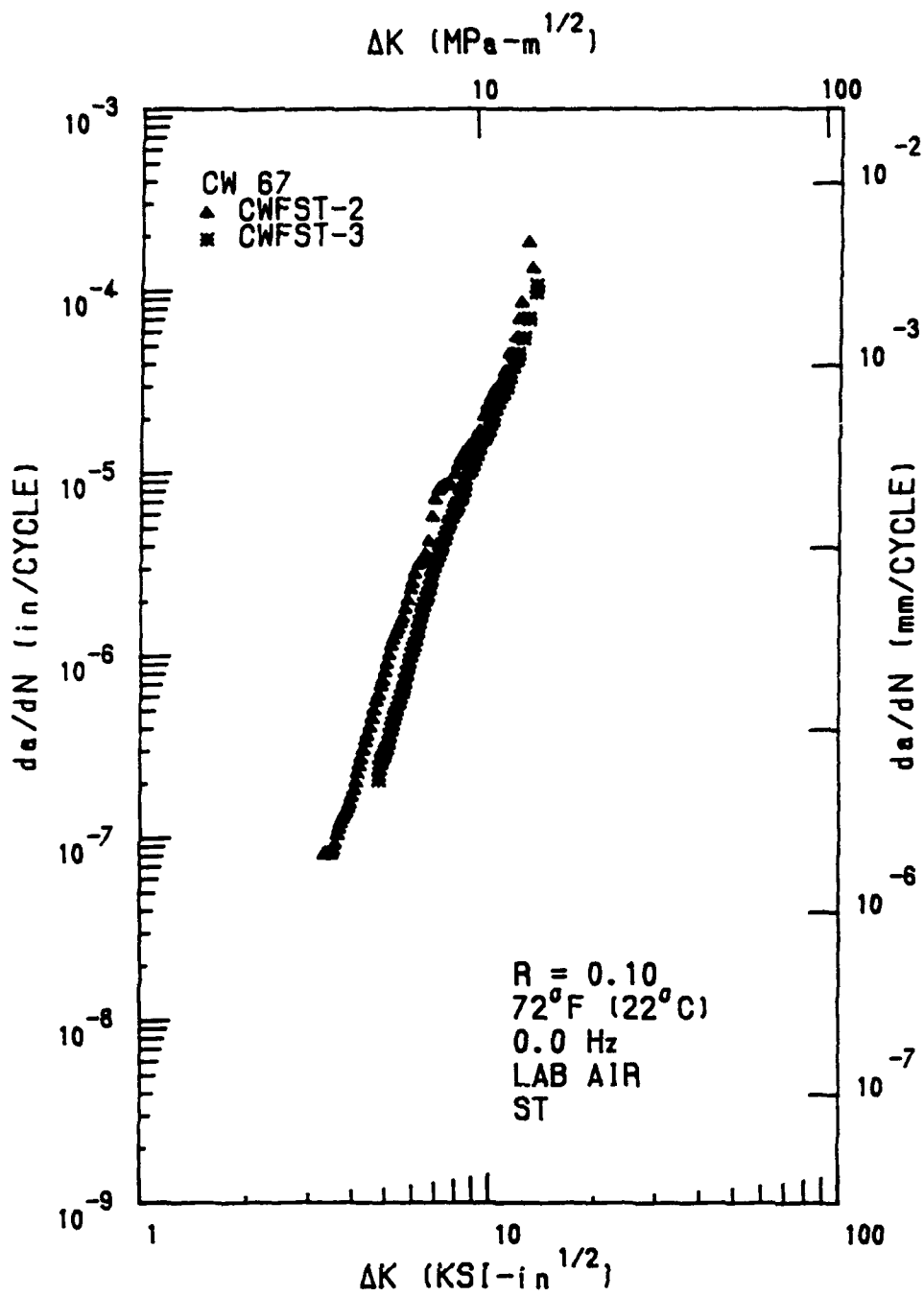


FIGURE S3. Fatigue Crack Growth Rate Data for CW67 Forging (S-T Orientation). Air Force.

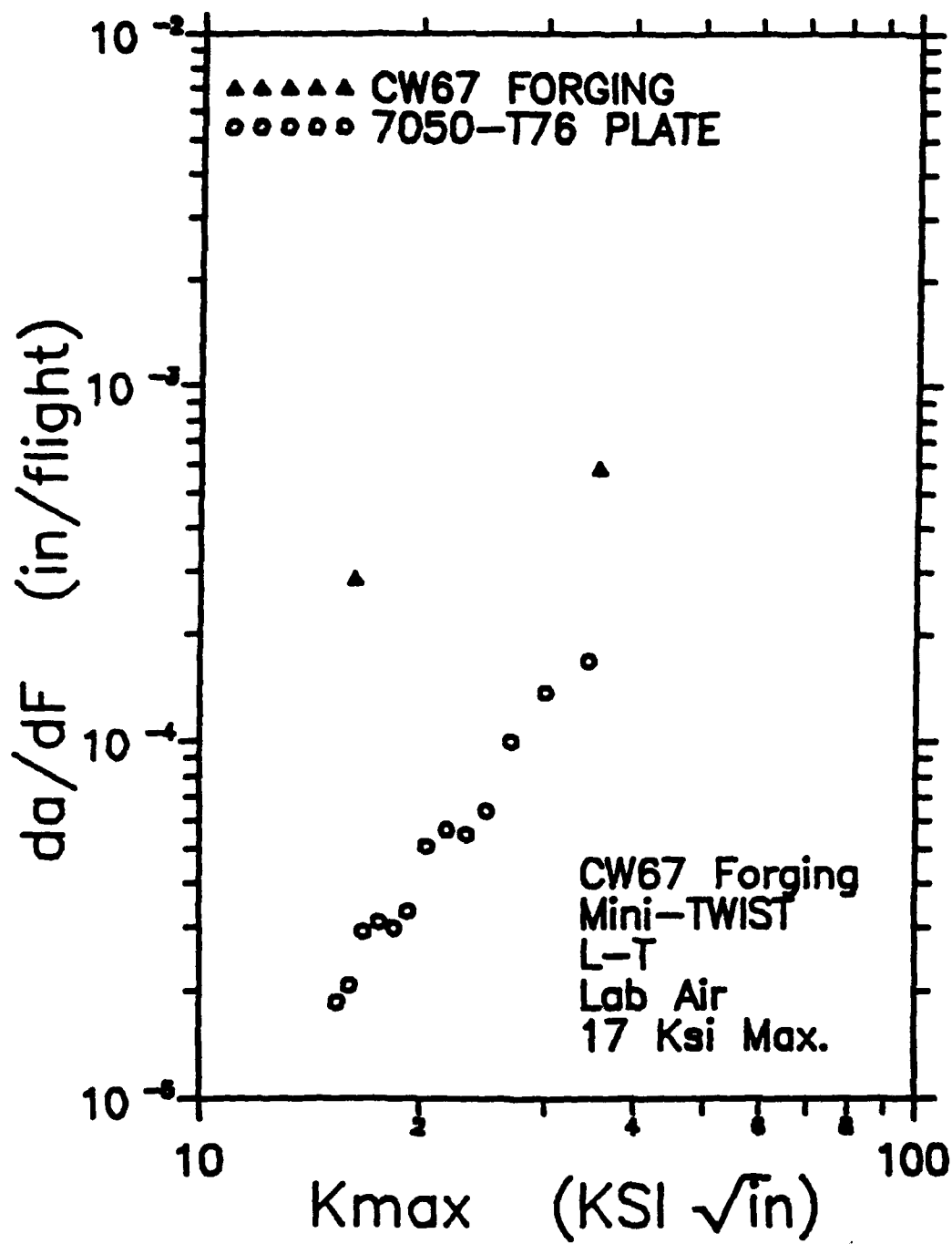


FIGURE S4. Comparison of CW67 Forging and 7050 Plate Mini-TWIST Spectrum Fatigue Crack Growth Rate Data (L-T Orientation). Air Force.

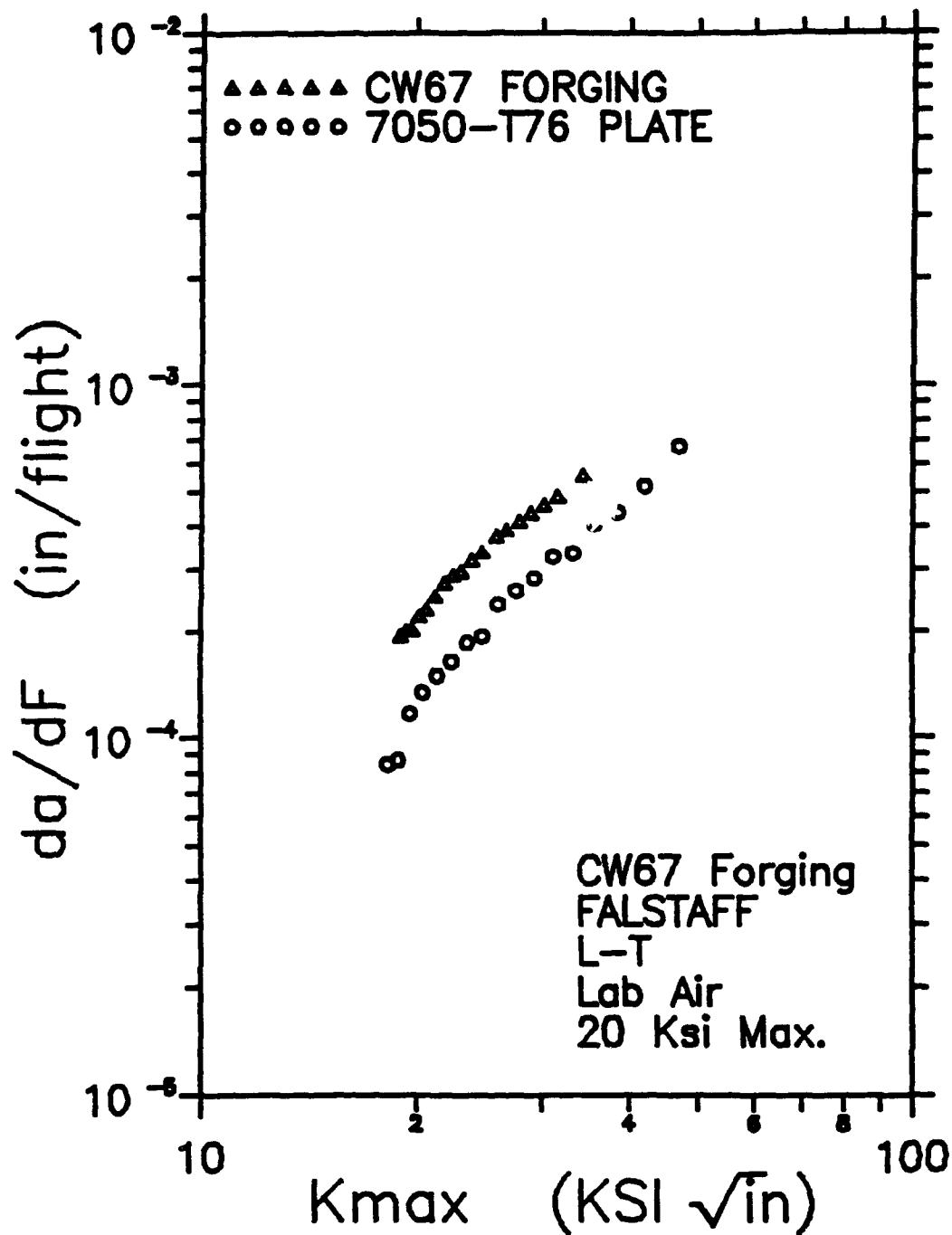


FIGURE S5. Comparison of CW67 Forging and 7050 Plate FALSTAFF Spectrum Fatigue Crack Growth Rate Data (L-T Orientation). Air Force.